AD-A163 490 MOORING SYSTEM DESIGN AND TIME DOMAIN SIMULATION OF A SEMISUBMERSIBLE BUOY(U) WATT (BRIAN) ASSOCIATES INC HOUSTON TX SEP 83 N62477-84-D-0165

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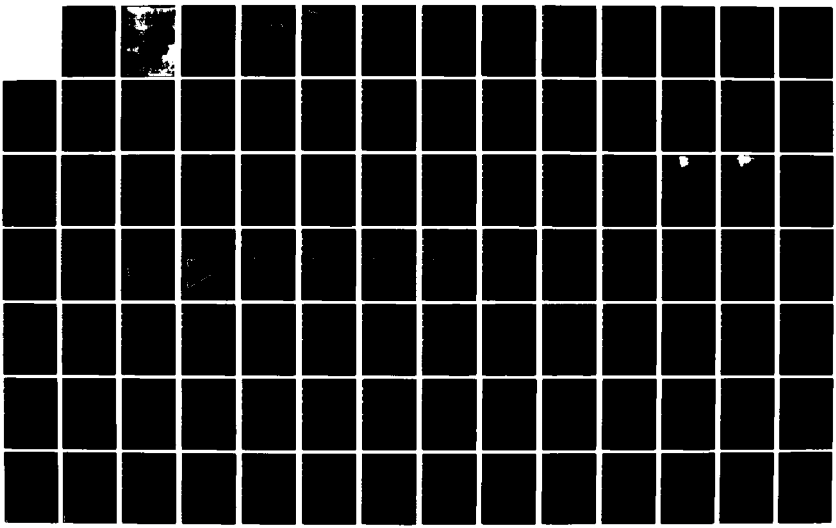

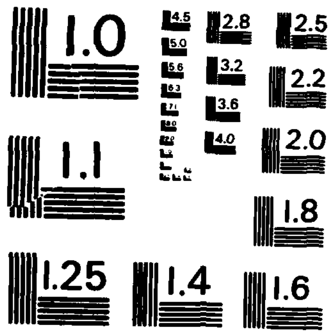

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MOORING SYSTEM DESIGN AND TIME DOMAIN SIMULATION OF A SEMISUBMERSIBLE BUOY

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NAVAL FACILITIES ENGINEERING COMMAND

MOORING SYSTEM DESIGN AND TIME DOMAIN SIMULATION OF A SEMISUBMERSIBLE BUOY

SEPTEMBER 1983

BRIAN WATT ASSOCIATES, INC.
Consulting Engineers

210/BWA

Brian Watt Associates, Inc.
Consulting Engineers
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Houston, Texas 77032
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September 9, 1983

Commanding Officer
Chesapeake Division
Naval Facilities Engineering Command
Building 212, Washington Navy Yard
Washington, D.C. 20374

Attn: Code FPO-1

Gentlemen:

Re: Contract N62477-83-D-0165, Engineering Analysis of Ocean Engineering Projects, Task 1

We enclose herein five (5) copies and one (1) reproducible copy of our final report for Task 1 of the referenced contract, with appendices.

We have enjoyed undertaking this project and look forward to working with you in the future.

Very truly yours,
BRIAN WATT ASSOCIATES, INC.

Robert C Byrd

Robert C. Byrd
Vice President

210/RCB:tr

Enclosures

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Rev. 1

1.0 INTRODUCTION

The following report presents the results of Task 1 of the open-end contract for Engineering Analysis of Ocean Engineering Projects for the Chesapeake Division, Naval Facilities Engineering Command.

This study has been conducted by Brian Watt Associates, Inc. (BWA) of Houston, Texas, and was performed under contract N62477-83-D-0165. It represents an effort of approximately 13 man-weeks. The study was performed as BWA Project No. 210.

1.1 Objectives

The goal of this task is to determine the steady-state dynamic mooring forces for a three-leg semisubmersible buoy, moored in water depths ranging from 100 to 400 feet, and being subjected to the survival wind, current, and wave for the site. The dynamic response of the moored semisubmersible to the survival environment will be simulated using Computer-Aided Design techniques.

1.2 Scope of Work

The scope of work as defined by the Department of Navy was as follows:

- Computer simulation of the dynamic response of the moored semisubmersible for the survival environment at water depths of 400, 250, 150 and 100 feet.

- Design of a mooring system for each water depth. The mooring will be composed of three equal lengths of ABS grade 2 stud link chain. This includes specifying the location of the mooring anchors, the length of the mooring chain, and the size of the mooring chain.

- The mooring will be designed such that the angle formed by the mooring leg, the anchor, and the ocean bottom does not exceed zero degrees and that the maximum tension does not

exceed 35 percent ($\pm$ 5 percent) of the chain's proof load at any time during the simulation.

- The mooring will be orientated such that one mooring leg will be required to resist all environmentally applied loads.

- The ballasting of the semisubmersible will be adjusted to compensate for the vertical load on the semisubmersible from the mooring legs before performing the dynamic simulation. The dynamic simulation will be continued until the steady-state response can be determined.

- The computer model used must be able to simulate the rigid body motions of the semisubmersible as function of time when subjected to the following external forces:

  1. Hydrodynamic loading on the submerged portion of the structure due to a series of nonlinear near-breaking waves.

  2. Hydrodynamic loading on the submerged portion of the structure due to a uniform current.

  3. Aerodynamic loading on the exposed portion of the structure due to a uniform wind.

  4. Concentrated loading on the structure due to the nonlinear catenary behavior of the three mooring legs.

- The computer model used does not have to be able to simulate environmental loading on the mooring chains, the internal stresses or deflections of the semisubmersible's structural components, or the dragging of the mooring leg anchors when overloaded.

1.3 Government Furnished Information

The following information was provided by the government in performance of this task:

1. An engineering drawing of the semisubmersible. These have been included in this report as Figures 1.1, 1.2 and 1.3.

2. Table 1.1 gives the survival wind, current and wave for each of the four water depths as specified by the government.

2.0 ANALYSIS AND MODEL DETAILS

This section discusses the software used for this task, the details of the computer model, the stream function analysis and the mooring system design procedure.

2.1 BWA Software

The main program used for the simulation, titled SEMI, is a FORTRAN code developed by BWA. This program simulates the motions of tension leg platforms and semisubmersibles in the time domain.

The program SEMI has the following capabilites:

- Wind loading
- Current loading
- Airy wave loading
- Stream Function wave loading
- Catenary moorings
- Tension leg moorings

In addition, the following software has been used as part of the design cycle.

FREQ: A frequency domain program for motion analysis of tension leg and catenary moored semisubmersibles. The program uses Airy wave theory, iterates for a best fit linearizing of the viscous damping and conducts eigenvalue, eigenvector analysis.

DAMS: A program for the design and analysis of single and multi-component mooring systems. Clump weights or buoys can be placed on the mooring lines. Restoring forces on the vessel, high line tension and vessel excursion are printed out.

Apart from the above software which has been developed by BWA, a finite element package ANSYS was run to obtain the system mass, radii of gyration and center of gravity.

2.2 Analysis Methodology

The analysis methodology consisted of iterating in a design loop until a workable system was achieved. The design loop incorporated the evaluation of the moorings, and the evaluation of the entire system in both the frequency domain and the time domain. This simulation cycle is shown in Figure 2.1; related software is listed in Table 2.1.

The analysis began with the estimation of the mean quasi static forces due to wind, wave and current loading. This estimation was made using a time domain analysis with the semi moored by tension legs as shown in Figure 2.2. The extreme length of the tension legs limited out-of-plane forces.

Once the mean forces were known, the magnitude of the first order motions was assumed. The mooring program DAMS then evaluated the proposed mooring systems. After a satisfactory mooring system was found, the required ballast for the operating draft was calculated. The finite element program ANSYS was used to determine the vessel CG and radii of gyration.

A freguency domain analysis was made to determine the mooring loads, and the oscillatory wave forces and motions. Any refinements to the mooring system were made at this point.

After all modifications were completed, the system was analyzed in the time domain. The results of the time domain analysis determined the acceptability of the system.

No effort has been made here to optimize the mooring system. Based on these results a further refinement could be undertaken and additional time domain analyses performed.

2.3 Model Generation

The model generation consisted of defining the semisubmersible by a set of nodes and elements. Each node point is defined by its X, Y, and Z coordinates in three dimensional space. Each element is described by its nodal end

points, its equivalent circular diameter, and its drag and added mass coefficients.

The fluid model generated for this analysis contained 219 elements. The elements were grouped as shown below:

Item	Quantity	No. of Elements
Pontoons	3	3 x 30
Columns	3	3 x 22
Lower Braces	6	6 x 5
Upper Braces	3	3 x 5
Deck Supports	3	3 x 5
Triangular Dampers	3	3 x 1
		219

Plots of the fluid model are shown in Figures 2.3 through 2.9.

The mooring system was attached at a point 12 ft above the bottom of each column. Figure 2.10 shows a plan view of the semisubmersible and the coordinate system adopted. The origin was 27 ft above the bottom and Z is positive upwards.

2.4 Element Size Considerations

In order to properly model the semisubmersible the element sizes must be small enough to avoid numerically induced errors during the solution. There are two criteria for determining the size of major elements exposed to fluid loadings. First, the element length should be less than 10% of the wave length, about 70 feet in this case. Second, a member should be divided into at least twenty elements to enable the proper calculation of inertias and other moment like quantities.

For this particular model, the major elements were divided much finer than required to insure the accurate attainment of moment and inertia quantities.

2.5 Added Mass and Drag Coefficients

The solution technique requires an added mass coefficient and a drag coefficient for flow normal to the element axis and for the exposed ends of the element.

There are two instances when the end of an element must be considered as exposed. The first and most obvious is when the end really is exposed. The second instance occurs at a connection (column to pontoon) where, for pressure equilibrium, a nonexposed end must be input as exposed.

The following values for the drag and added mass coefficients were used:

Item	C_D Normal	C_A Normal	C_D End	C_A End
Cylinders	.62	.90	0.4	1.0
Triangles	0.0	0.0	2.0	2.83

The following reference was used in obtaining these values "Mechanics of Wave Forces on Offshore Structures, Turgut Sarpkaya & Michael Isaacson, Van Nostrand Reinhold Company." Figures 3.20 and 3.21 from this reference give the variation of C_D and C_A and have been included as Figure 2.11 in this report. The values of Reynolds number and Keulegan-Carpenter number required to use these figures are shown below:

Item	R_e	K	C_d	C_m	C_a
Pontoons	1.93 x 10-5	90.93	0.62	1.90	0.90
Columns and Braces	2.09 x 10-5	84.00	0.62	1.90	0.90

The coefficients for the triangular dampers were obtained by direct computation.

2.6 ANSYS Modeling

The basic fluid model of the semisubmersible was input into the finite element program ANSYS. This step was necessary to compute the system mass, center of gravity, and radii of gyration.

The ANSYS model differed from the fluid model in that it required dummy elements to connect the members of the fluid model.

The ANSYS element used to represent the structural members of the semisubmersible was the 3-D pipe element, STIF42. The appropriate values for Young's Modulous, Poisson's ratio, density, diameter and thickness were input. To model the ballast water, the STIF42 element was used again. The wall thickness was set equal to the radius, Young's Modulous was set equal to 1, and Poisson's ratio was set equal to zero.

The results from ANSYS giving the centers of gravity and the radii of gyration are shown in Table 2.2

2.7 Stream Function Analysis

A stream function analysis was performed for the four design cases to obtain vertical and horizontal velocities, accelerations, and presssures. This data is output to a binary file which is read as input to the frequency and time domain programs.

The governing equation for stream function modeling is the Laplace equation. The formulation satisfies kinematic boundary conditions at the bottom and free surface, and the dynamic free surface boundary condition. The water particle kinematics are corrected by a vector addition of the current (Ref.: Dalrymple, R. A., "A Finite Amplitude Wave on a Linear Shear Current," J. Geophysical Research, Vol. 79, pp. 4498-4504, 1974). The bottom and surface currents are specified and a linear interpolation is undertaken. As the wave water particle velocities are corrected for the current, the external imposed current velocity for drag computation in the time domain analysis has been set to zero.

The stream function program used for this analysis was developed at Coastal and Offshore Inc. Input requirements include: wave height, wave period, water depth, bottom and surface currents, the order of the problem, number of computational points over 1/2 the wave, maximum number of solution iterations.

The actual input for the four cases is shown in Table 2.3.

2.8 Aerodymanic Loading

The wind loading was estimated based on section 3.5.2 of the "ABS Rules for Building and Classing Mobile Offshore Drilling Units - 1980". The total estimated wind force was 40 Kips acting at 29.4 ft above waterline. Table 2.4 gives the details of the computation and Figure 2.12 shows the semisubmersible projected area used in the calculations.

2.9 Mooring System

The mooring systems used in this study to restrain the semisubmersible were conventional, single-component spread moorings. The basic catenary relationships used for mooring system design are shown in Figure 2.13.

Table 2.5 gives the pertinent properties for various sizes of chain. The maximum chain size allowed was limited to 6 in. This is the largest size commercially produced at the present time without the need for extensive expansion of manufacturing facilities.

Figure 2.14 shows the relationship between scope and water depth used in this study. The scope-water depth curve is nonlinear and corresponds to a constant line length of 2,000 ft.

The coefficient of bottom friction used throughout the study was 0.80. The design of the mooring system at each depth followed the same general procedure:

(1) Estimate the mean quasi-static force due to wind, wave, and current and the magnitude of 1st order motions using a time domain analysis of the semimoored by tension legs.

(2) Estimate a starting anchor location based on the line length and water depth (see Figure 2.15).

(3) Perform a series of mooring analysis varying the chain size. Evaluate systems with respect to high line tension and anchor forces when subjected to forces and motions established in Item 1 (see Table 2.6).

(4) Select the candidate system based on a review of the results.

(5) Perform another series of runs, this time varying the anchor location. Evaluate the system with respect to high line tension and anchor forces when subjected to the forces and motions established in Item 1 (see Table 2.7). Select final anchor location.

(6) Adjust ballasting of semi to account for the vertical load arising from the vertical component of mooring line tension and calculate new CG and radii of gyration using ANSYS program.

(7) Perform a frequency domain analysis of the trial mooring system to determine natural periods, R.A.O.'s, and phase angles of the system, and to obtain an estimate of the maximum line tensions and anchor loads.

(8) Revise system based on results of frequency domain analysis, if required.

(9) Perform time domain analysis of system.

(10) Review time domain results to determine system acceptablity/rejection.

3.0 RESULTS

Appendix A to this report contains the frequency domain results and time history plots for each of the design cases.

Table 3.1 gives the parameters for each of the four design cases.

A time step of 0.25 seconds was selected in the time domain simulation. The simulation was carried until steady state was acheived. This corresponds to 400 time steps with a total span of 100 seconds.

The maximum chain size was limited to 6 in. This limit was based on the maximum chain size commercially available from present installations. It was felt that the economics of the problem would not permit any special arrangements for larger chain sizes.

A summary of the results from the frequency domain and time domain are included here.

Table 3.2 gives the results from the frequency domain analysis. The important quantities in this table are the natural periods, response amplitude operators and phase angle in surge, heave, and pitch.

Summary results from the time domain simulation are given in Tables 3.3 through 3.6. The results from this simulation are:

Water Depth	Mooring Chain	Peak Tension (% Proof Read)
412 ft	5 in.	30.84
262 ft	5 in.	31.26
162 ft	6 in.	59.8
112 ft	6 in.	114.8

Figures 3.1, 3.2, and 3.3 give the mooring system characteristics for water depths of 412 ft, 262 ft, and 162 ft. Figure 3.4 gives the variation of the peak horizontal dynamic force against water depth.

4.0 CONCLUSIONS & RECOMMENDATIONS

Based on the preliminary study conducted here, a feasible mooring system, that satisfies all the design criteria defined by the U.S. Navy, has been designed for water depths of 400 ft and 250 ft. The designed mooring system consists of a 5 in. diameter, Grade 2 stud link chain. The length of chain was 2,000 ft for all depths.

No effort has been made under this task to optimize or refine the mooring system. Based on these results, the conclusion is that a 4½ in. diameter chain could be used. Also, the length of chain needs to be optimized and can be reduced in most cases.

All the evaluation in this task was for a survival environment. The response of the system to a design environment with operational constraints also needs to be examined.

A feasible solution was not found for the 150 ft and 100 ft depth. For the 150 ft depth the peak line tension is 59.8% with a 6 in. diameter chain. It is our opinion that an optimization exercise may yield a workable solution. For the 100 ft depth, the peak line tension is 114.8%.

The coupled response of surge, heave, and pitch plays a dominant role in the behavior of the mooring system. At water depths of 400 and 250 ft, the maximum surge displacement is coupled with a negative heave (downwards) and a positive pitch. This results in a slackening of the most loaded line and, thereby, reducing the tension to acceptable levels. At the 150 ft water depth, the maximum surge displacement is coupled with zero heave and a positive pitch. At the 100 ft water depth, the maximum surge displacement is coupled with a positive heave (upwards) and a sharp variation in the pitch response from negative 22 degrees to a positive 9 degrees within a very narrow band. The net result is to make the mooring chain taut, causing high line tensions.

In our opinion, further evaluation of the system needs to be conducted at the 150 ft water depth. A more thorough time domain simulation with irregular sea states, to alleviate the strong dependence on a particular wave frequency and the resulting phase relationship, is recommended to prove the system performance.

GFI for Contract 62477-83-D-0165

Survival Environment

- Wind 150 knots constant

Water Depth	100'	150'	250'	400'
Wave Height	61'	64'	72'	84'
Wave Period	13.6 sec	13.6 sec	14 sec	14.6 sec
Current				
Surface	2 kt	2 kt	2 kt	2 kt
Bottom	1 kt	1 kt	1 kt	1 kt
Storm Current				
Surface	1 kt	1 kt	1 kt	1 kt
Tide ±	7'	7'	7'	7'
Storm Surge +	5'	5'	5'	5'

TABLE 1-1 - ENVIRONMENT SPECIFICATION

BRIAN WATT ASSOCIATES, INC. CONSULTING ENGINEERS HOUSTON, TEXAS	CLIENT: U.S. NAVY	FILING CODE:
	PROJECT:	JOB NO. 210
		PAGE 2 OF 2
SYSTEM:		ORIGINATOR:
CALCULATION FOR: SOFTWARE DESCRIPTION		DATE:
		REVIEWER:
		DATE:
		REVISION:
		RESULTS:

MAJOR PROGRAMS

FREQ - frequency domain analysis of semisubmersibles
TIME - time domain analysis of semisubmersibles

MINOR PROGRAMS

STREAM - stream function wave theory
DAMS - dynamic analysis of mooring systems
CAT - catenary mooring force/displacement matrix generator

SUPPORTING PROGRAMS

YGEN - model generation program
VPLOT - plots vessel geometry
FPLOTI - RAO & phase plotting program (frequency)
TPLOTI - displacement velocity plotting (time)
LPLOT - mooring force plotting (time)

TABLE 2.1 BWA NAVAL ARCHITECTURE SOFTWARE

FILING CODE:

CASE	CHAIN SIZE (IN)	BALLAST WEIGHT (TONS)	MOORING WEIGHT (TONS)	TOTAL WEIGHT (TONS)	XCG (ft)	YCG (ft)	ZCG (ft)	RXX (ft)	RYY (ft)	RZZ (ft)
FREE FLOATING	—	186.3	—	251.4	0.0	0.0	-19.8	22.6	22.6	28.4
D = 112'	6	120.0	66.4	251.5	0.0	0.0	-18.4	24.5	24.5	30.3
D = 162'	6	119.9	69.4	254.4	0.0	0.0	-18.5	24.5	24.5	30.3
D = 162'	5	130.0	57.8	252.9	0.0	0.0	-18.8	24.1	24.1	30.0
D = 262'	6	59.6	128.9	253.6	0.0	0.0	-15.9	26.5	26.5	32.1
D = 262'	5	99.9	88.0	253.0	0.0	0.0	-17.9	25.2	25.2	31.1
D = 412'	5	23.7	164.2	253.0	0.0	0.0	-12.9	26.9	26.9	31.5

NOTE: SEMI + PAYLOAD = 65.1 TONS

TABLE 2.2 CENTER OF GRAVITY AND RADII OF GYRATION
(OBTAINED FROM ANSYS)

BRIAN WATT ASSOCIATES, INC.
CONSULTING ENGINEERS
HOUSTON, TEXAS

CLIENT: U. S. NAVY
PROJECT:
FILING CODE:
JOB NO.
PAGE OF
SYSTEM:
ORIGINATOR:
DATE:
CALCULATION FOR: STREAM FUNCTION INPUT PARAMETERS
REVIEWER:
DATE:
REVISION:
RESULTS:

CASE	DEPTH	WAVE HEIGHT	WAVE PERIOD	BOTTOM CURRENT	SURFACE CURRENT	ORDER	NTHTS	MAX ITERATIONS	DEPTH ANALYZED
1	112'	61'	13.6 s	1.659 f/s	5.067 f/s	10	[illegible]	20	100'
2	162'	64'	13.6 s	1.659 f/s	5.067 f/s	10	[illegible]	20	100'
3	262'	72'	14.0 s	1.659 f/s	5.067 f/s	10	[illegible]	20	100'
4	412'	84'	14.6 s	1.659 f/s	5.067 f/s	10	[illegible]	20	100'

TABLE 2.3 STREAM FUNCTION INPUT DATA

FILING CODE:

JOB # 210 DATE: 8/10/83.

WIND FORCES ON SEMISUBMERSIBLE BUOY

ITEM	C_h	C_s	QUANTITY	AREA (FT^2)	$C_h C_s A$	Centroid Above WL
Exterior Columns	1.0	0.5	2	215.0	107.5	8.5'
Center Column	1.0	0.5	1	95.0	47.5	7.5'
Braces	1.0	0.5	2	70.8	35.4	8'
Deck Frame	1.0	1.0	1	117.3	117.3	16'
Deck House	1.0	1.0	1	48.0	48.0	21'
Mast	1.1	1.5	1	41.7	68.8	50'
Top Dome	1.1	1.0	1	50.3	55.3	75'
Bottom Dome	1.1	1.0	1	50.3	55.3	67'

From section 3.5.2 "A.B.S. Rules for Building and Classing Mobile Offshore Drilling Units - 1980"

$$F_W = 0.00338\, V_K^2 \times \Sigma C_h C_s A \text{ lbs}$$

$$F_W = 40 \text{ Kips}$$

- Centroid = 29.4 ft above waterline

TABLE 2.4 WIND FORCE CALCULATIONS

CHAIN SIZE (IN)	AIR WEIGHT (LB/FT)	ABS GRADE 2 PROOF LOAD (LBS)	ABS GRADE 2 BREAK LOAD (LBS)
$2\frac{1}{2}$	62.0	346,000	484,000
$2\frac{3}{4}$	75.4	413,000	578,000
3	90.2	485,000	679,000
$3\frac{1}{4}$	106.0	562,000	787,000
$3\frac{1}{2}$	123.4	643,000	900,000
$3\frac{3}{4}$	140.7	728,000	1,019,000
4	159.2	816,000	1,143,000
$4\frac{1}{4}$	182.3	908,000	1,272,000
$4\frac{1}{2}$	205.3	1,004,000	1,405,000
$4\frac{3}{4}$	225.1	1,102,000	1,543,000
5	253.0	1,203,000	1,685,000
* $5\frac{3}{8}$	293.0	1,359,000	1,903,000
* $5\frac{5}{8}$	318.9	1,466,000	2,052,000
$5\frac{3}{4}$	333.9	1,520,000	2,128,000
6	361.9	1,629,000	2,280,000

* $5\frac{1}{4}$ & $5\frac{1}{2}$ IN. SIZES NOT LISTED, NEXT SIZE MANUFACTURED SHOWN

$$A = 2(\pi D^2/4) = \pi D^2/2$$

$$E_{CHAIN} = 29{,}000{,}000 \text{ psi}$$

TABLE 2.5 CHAIN PROPERTIES

EFFECTIVE WATER DEPTH = 412'

ANCHOR LOCATION: 1775.0' LENGTH OF LINE: 2000.0' ABS GRADE: 2

CHAIN SIZE (IN)	LINE PRETENSION		QUASI-STATIC FORCES ONLY						QUASI-STATIC + 1ST ORDER MOTIONS					
			OFFSET	MAX. LINE TENSION		MIN. LB	ANCHOR LOAD		OFFSET	MAX. LINE TENSION		MIN. LB	ANCHOR LOAD	
	KIPS	% PROOF	FT	KIPS	% PROOF	FT	HA (KIPS)	VA (KIPS)	FT	KIPS	% PROOF	FT	HA	VA
4	77.6	9.5	119.7	213	26.1	970	50.5	—	161.7	477	58.5	406	378	—
4½	100.0	10.0	107.7	233	23.2	1067	—	—	149.7	487	48.5	595	331	—
5	123.2	10.2	98.3	254	21.1	1132	—	—	140.3	489	40.6	736	272	—
5⅝	155.4	10.6	87.3	283	19.3	1194	—	—	129.3	506	34.5	870	203	—
6	176.4	10.8	82.0	302	18.5	1224	—	—	124.0	514	31.5	934	154	—

SIZE FOR 1ST TRIAL

MEAN QUASI STATIC FORCE ≅ 150.0'

MAX. 1ST ORDER MOTIONS: SURGE ≅ 42.0'
SWAY = —
HEAVE = —

MIN. LB = MINIMUM LENGTH OF CHAIN ON BOTTOM

TABLE 2.6 PARAMETRIC STUDY OF CHAIN SIZES FOR D=412'

EFFECTIVE WATER DEPTH = 412'

CHAIN SIZE: 5" ABS GRADE: 2 PROOF LOAD: 1203^K C.B.S.: 1685^K LINE LENGTH: 2000'

ANCHOR LOCATION	LINE PRETENSION		QUASI-STATIC FORCES ONLY						QUASI-STATIC + 1ST ORDER MOTIONS					
			OFFSET	MAX. LINE TENSION		MIN. LB	ANCHOR LOAD		OFFSET	MAX. LINE TENSION		MIN. LB	ANCHOR LOAD	
(FT)	KIPS	% PROOF	FT	KIPS	% PROOF	FT	HA (KIPS)	VA (KIPS)	FT	KIPS	% PROOF	FT	HA	VA
1650	90.8	7.5	217.3	238	19.8	1165	—	—	259.3	440.2	36.6	809	210	—
1700	98.4	8.2	168.0	238	19.8	1164	—	—	210.0	444.0	36.9	805	215	—
1750	112.2	9.3	121.2	246	20.5	1145	—	—	163.2	463.9	38.6	771	242	—
1800	138.9	11.5	77.0	265	22.0	1107	—	—	119.0	530.6	44.1	680	324	—
1850	197.4	16.4	40.5	315	26.2	1011	50	—	82.5	708	58.9	452	541	—

MEAN QUASI STATIC FORCE = 150^K

MAX. 1ST ORDER MOTIONS: SURGE = 42'
SWAY = —
HEAVE = —

MIN. LB = MINIMUM LENGTH OF CHAIN ON BOTTOM

TABLE 2.7 PARAMETRIC STUDY OF ANCHOR LOCATION (PRETENSION) FOR D = 412'

WATER DEPTH (FT)	112'	162'	262'	412'
WAVE HEIGHT (FT)	61'	64'	72'	84'
WAVE PERIOD (SEC)	13.6	13.6	14.0	14.6
WIND SPEED (KN)	150	150	150	150
CURRENT (FT/SEC)				
BOTTOM	1.69	1.69	1.69	1.69
SURFACE	5.07	5.07	5.07	5.07

TABLE 3.1 PARAMETERS FOR DESIGN CASES

WATER DEPTH (FT)	112	162	262	262	412
WAVE HEIGHT (FT)	61	64	72	72	84
WAVE PERIOD (SECS)	13.60	13.60	14.00	14.00	14.60
CHAIN SIZE (IN)	6	6	6	5	5
EST. STATIC OFFSET* (FT)	30.0		121.4	133.2	121.2
NATURAL PERIOD					
SURGE	24.71	100.30	36.46	45.10	30.94
HEAVE	10.51	11.45	10.20	11.17	9.70
PITCH	8.68	10.10	10.49	10.23	12.62
SURGE RAO	1.2142	1.0506	0.9804	0.9668	0.9331
PHASE ANGLE	72.50	36.52	46.94	43.02	56.74
HEAVE RAO	0.6635	0.7925	0.8288	0.8364	0.8516
PHASE ANGLE	-152.50	-163.05	-159.97	-163.25	-158.85
PITCH RAO	0.7688	0.184	0.1245	0.1339	0.1243
PHASE ANGLE	-158.32	-59.57	-92.58	-78.28	-126.94

* BASED ON HORIZONTAL STATIC FORCE = 150 KIPS

TABLE 3.2 SUMMARY OF FREQUENCY DOMAIN ANALYTICAL RESULTS

SUMMARY OF RESULTS

EFFECTIVE WATER DEPTH = 412 FT

DESIGN WAVE HEIGHT (FT) = 84.0
WAVE PERIOD (SEC) = 14.6
MAX CREST ELEVATION (FT) = +47.41
MIN TROUGH ELEVATION (FT) = - 36.34
MEAN ELEVATION (FT) = +5.54

MAX/MIN SURGE OFFSET (FT) = -147.8/-71.4
MEAN SURGE OFFSET (FT) = -109.6
MAX 1st ORDER MOTIONS (FT) = ± 38.2

MAX/MIN HEAVE OFFSET (FT) = -33.5/24.5
MEAN HEAVE OFFSET (FT) = -4.5
MAX 1st ORDER MOTION (FT) = ± 29.5

MAX/MIN PITCH ANGLE (DEG) = 12.5/8.6
MEAN PITCH ANGLE (DEG) = 2.0
MAX 1st ORDER MOTION (DEG) = ± 10.5

MAX HORIZONTAL FORCE @ VESSEL (KIPS) = 285
MIN HORIZONTAL FORCE @ VESSEL (KIPS) = 58
MEAN HORIZONTAL FORCE @ VESSEL (KIPS) = 171.5

MAX VERTICAL FORCE @ VESSEL (KIPS) = 237
MIN VERTICAL FORCE @ VESSEL (KIPS) = 126
MEAN VERTICAL FORCE @ VESSEL (KIPS) = 181.5

MAX TENSION @ VESSEL (KIPS) = 371
MIN TENSION @ VESSEL (KIPS) = 139
MEAN TENSION @ VESSEL (KIPS) = 255

MAX HORZ. FORCE @ ANCHOR (KIPS) = 138
MIN HORZ. FORCE @ ANCHOR (KIPS) = 0

MAX VERTICAL FORCE @ ANCHOR (KIPS) = –
MIN VERTICAL FORCE @ ANCHOR (KIPS) = –

CHAIN DIAMETER (IN) = 5.0
LENGTH OF CHAIN (FT) = 2,000
LOCATION OF ANCHOR (FT) = 1,750
PROOF LOAD (KIPS) = 1,203

(PEAK TENSION / PROOF LOAD) × 100 = 30.84 %

TABLE 3.3 SUMMARY RESULTS – DEPTH 412 FT.

SUMMARY OF RESULTS

EFFECTIVE WATER DEPTH = 262 FT

DESIGN WAVE HEIGHT (FT) = 72.0
WAVE PERIOD (SEC) = 14.0
MAX CREST ELEVATION (FT) = +42.03
MIN TROUGH ELEVATION (FT) = -29.85
MEAN ELEVATION (FT) = +6.08

MAX/MIN SURGE OFFSET (FT) = -149.28/-74.65
MEAN SURGE OFFSET (FT) = -112.0
MAX 1st ORDER MOTIONS (FT) = ± 37.3

MAX/MIN HEAVE OFFSET (FT) = -35.14/23.90
MEAN HEAVE OFFSET (FT) = -5.62
MAX 1st ORDER MOTION (FT) = ± 29.5

MAX/MIN PITCH ANGLE (DEG) = 11.87/-23.55
MEAN PITCH ANGLE (DEG) = -5.84
MAX 1st ORDER MOTION (DEG) = ± 17.7

MAX HORIZONTAL FORCE @ VESSEL (KIPS) = 325
MIN HORIZONTAL FORCE @ VESSEL (KIPS) = 31
MEAN HORIZONTAL FORCE @ VESSEL (KIPS) = 178

MAX VERTICAL FORCE @ VESSEL (KIPS) = 188
MIN VERTICAL FORCE @ VESSEL (KIPS) = 80
MEAN VERTICAL FORCE @ VESSEL (KIPS) = 134

MAX TENSION @ VESSEL (KIPS) = 376
MIN TENSION @ VESSEL (KIPS) = 80
MEAN TENSION @ VESSEL (KIPS) = 228

MAX HORZ. FORCE @ ANCHOR (KIPS) = 175
MIN HORZ. FORCE @ ANCHOR (KIPS) = 0

MAX VERTICAL FORCE @ ANCHOR (KIPS) = 0
MIN VERTICAL FORCE @ ANCHOR (KIPS) = 0

CHAIN DIAMETER (IN) = 5.0
LENGTH OF CHAIN (FT) = 2,000
LOCATION OF ANCHOR (FT) = 1,800
PROOF LOAD (KIPS) = 1,203

(PEAK TENSION / PROOF LOAD) × 100 = 31.26 %

TABLE-3.4 SUMMARY RESULTS - DEPTH 262 FT

SUMMARY OF RESULTS

EFFECTIVE WATER DEPTH = 162 FT

DESIGN WAVE HEIGHT (FT) = 64.0
WAVE PERIOD (SEC) = 13.6
MAX CREST ELEVATION (FT) = 40.58
MIN TROUGH ELEVATION (FT) = −23.17
MEAN ELEVATION (FT) = +8.71

MAX/MIN SURGE OFFSET (FT) = 1.32/−125.9
MEAN SURGE OFFSET (FT) = −87.3
MAX 1st ORDER MOTIONS (FT) = ± 38.6

MAX/MIN HEAVE OFFSET (FT) = 18.69/−24.70
MEAN HEAVE OFFSET (FT) = −3.01
MAX 1st ORDER MOTION (FT) = ± 21.7

MAX/MIN PITCH ANGLE (DEG) = 18.3/−24.8
MEAN PITCH ANGLE (DEG) = −5.4
MAX 1st ORDER MOTION (DEG) = ± 19.4

MAX HORIZONTAL FORCE @ VESSEL (KIPS) = 939
MIN HORIZONTAL FORCE @ VESSEL (KIPS) = 0
MEAN HORIZONTAL FORCE @ VESSEL (KIPS) = 470

MAX VERTICAL FORCE @ VESSEL (KIPS) = 264
MIN VERTICAL FORCE @ VESSEL (KIPS) = 57
MEAN VERTICAL FORCE @ VESSEL (KIPS) = 160.5

MAX TENSION @ VESSEL (KIPS) = 974
MIN TENSION @ VESSEL (KIPS) = 50
MEAN TENSION @ VESSEL (KIPS) = 512

MAX HORZ. FORCE @ ANCHOR (KIPS) = 652
MIN HORZ. FORCE @ ANCHOR (KIPS) = 0

MAX VERTICAL FORCE @ ANCHOR (KIPS) = 0
MIN VERTICAL FORCE @ ANCHOR (KIPS) = 0

CHAIN DIAMETER (IN) = 6.0
LENGTH OF CHAIN (FT) = 3,000
LOCATION OF ANCHOR (FT) = 2,850
PROOF LOAD (KIPS) = 2,280

(PEAK TENSION / PROOF LOAD) × 100 = 59.8 %

TABLE-3.5 SUMMARY RESULTS - DEPTH 162 FT

SUMMARY OF RESULTS

EFFECTIVE WATER DEPTH = 112 FT

DESIGN WAVE HEIGHT (FT) = 61.0
WAVE PERIOD (SEC) = 13.6
MAX CREST ELEVATION (FT) = 43.65
MIN TROUGH ELEVATION (FT) = −16.85
MEAN ELEVATION (FT) = +13.40

MAX/MIN SURGE OFFSET (FT) = −43.62/18.35
MEAN SURGE OFFSET (FT) = −12.63
MAX 1st ORDER MOTIONS (FT) = ± 31.0

MAX/MIN HEAVE OFFSET (FT) = 17.18/−15.13
MEAN HEAVE OFFSET (FT) = +1.03
MAX 1st ORDER MOTION (FT) = ± 16.15

MAX/MIN PITCH ANGLE (DEG) = 9.94/−22.48
MEAN PITCH ANGLE (DEG) = −6.27
MAX 1st ORDER MOTION (DEG) = ± 16.2

MAX HORIZONTAL FORCE @ VESSEL (KIPS) = 1843
MIN HORIZONTAL FORCE @ VESSEL (KIPS) = 0
MEAN HORIZONTAL FORCE @ VESSEL (KIPS) = 927

MAX VERTICAL FORCE @ VESSEL (KIPS) = 322
MIN VERTICAL FORCE @ VESSEL (KIPS) = 0
MEAN VERTICAL FORCE @ VESSEL (KIPS) = 161

MAX TENSION @ VESSEL (KIPS) = 1871
MIN TENSION @ VESSEL (KIPS) = 0
MEAN TENSION @ VESSEL (KIPS) = 935.5

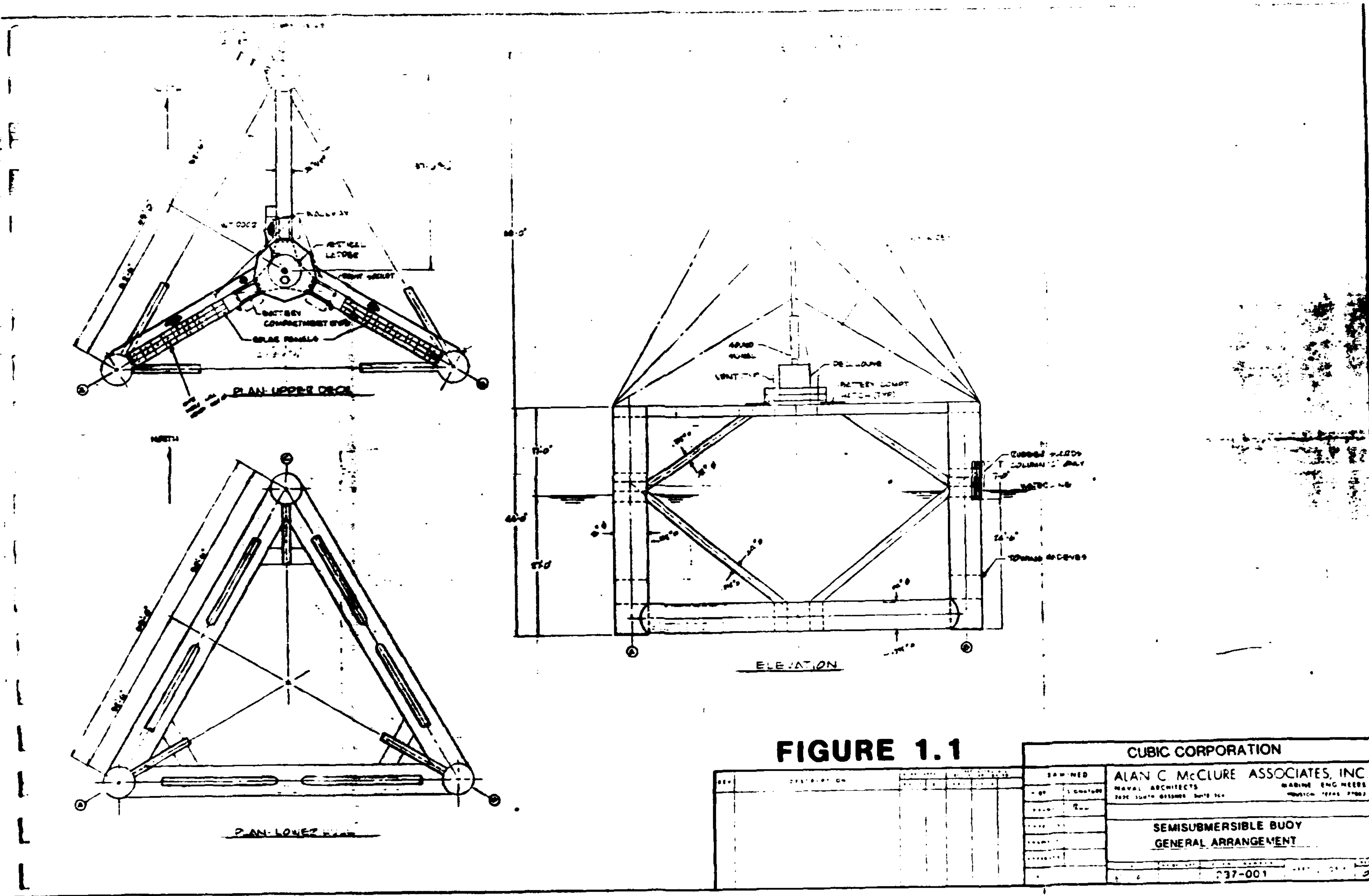
MAX HORZ. FORCE @ ANCHOR (KIPS) = 1597
MIN HORZ. FORCE @ ANCHOR (KIPS) = 0

MAX VERTICAL FORCE @ ANCHOR (KIPS) = 0
MIN VERTICAL FORCE @ ANCHOR (KIPS) = 0

CHAIN DIAMETER (IN) = 6
LENGTH OF CHAIN (FT) = 2,000
LOCATION OF ANCHOR (FT) = 1,950
PROOF LOAD (KIPS) = 1,629

(PEAK TENSION / PROOF LOAD) × 100 = 114.8 %

TABLE-3.6 SUMMARY RESULTS - DEPTH 112 FT



PLAN-UPPER DECK
PLAN-LOWER
NORTH
ELEVATION
CUBIC CORPORATION
ALAN C. McCLURE ASSOCIATES, INC
NAVAL ARCHITECTS
MARINE ENGINEERS
SEMISUBMERSIBLE BUOY
GENERAL ARRANGEMENT
237-001

FIGURE 1.1

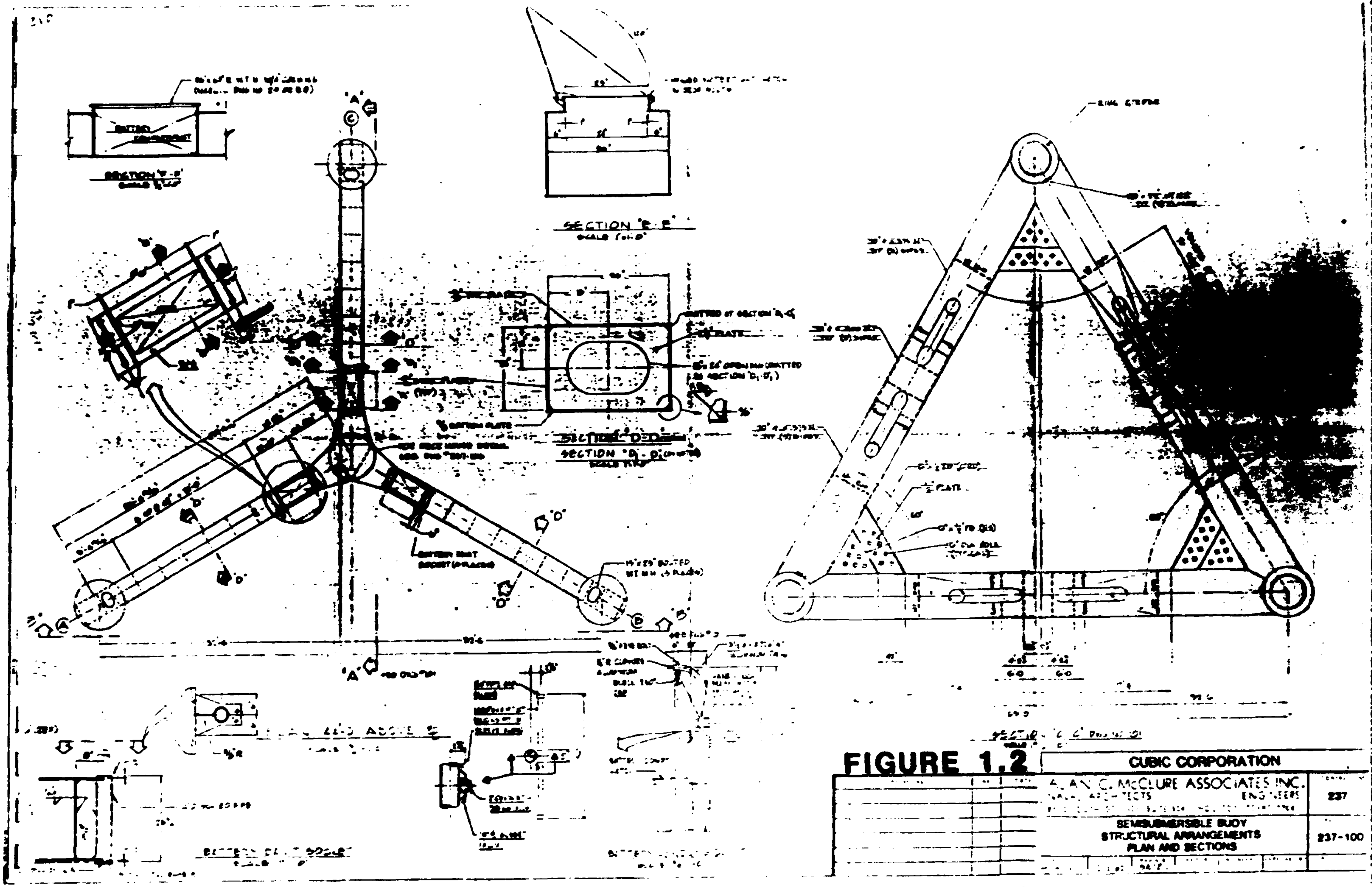
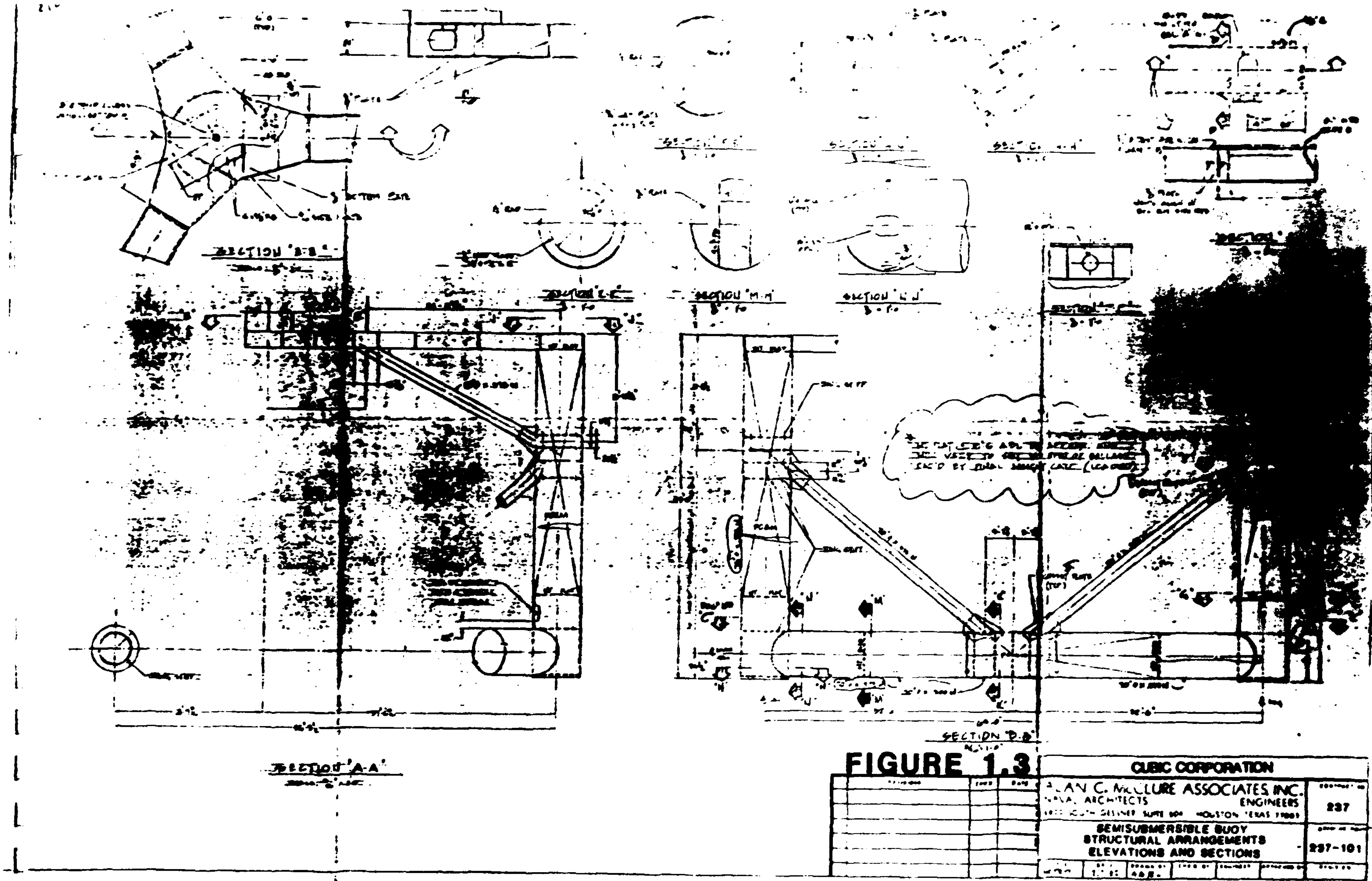

SECTION 'E-E'
SECTION 'D-D'
CUBIC CORPORATION
ALAN C. McCLURE ASSOCIATES INC.
SEMISUBMERSIBLE BUOY
STRUCTURAL ARRANGEMENTS
PLAN AND SECTIONS
237
237-100

FIGURE 1.2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SECTION 'E-E'
SECTION 'M-M'
SECTION 'N-N'
SECTION 'A-A'
SECTION 'D-D'
CUBIC CORPORATION
ALAN C. McCLURE ASSOCIATES INC.
NAVAL ARCHITECTS
ENGINEERS
HOUSTON TEXAS
237
SEMISUBMERSIBLE BUOY
STRUCTURAL ARRANGEMENTS
ELEVATIONS AND SECTIONS
237-101

FIGURE 1.3

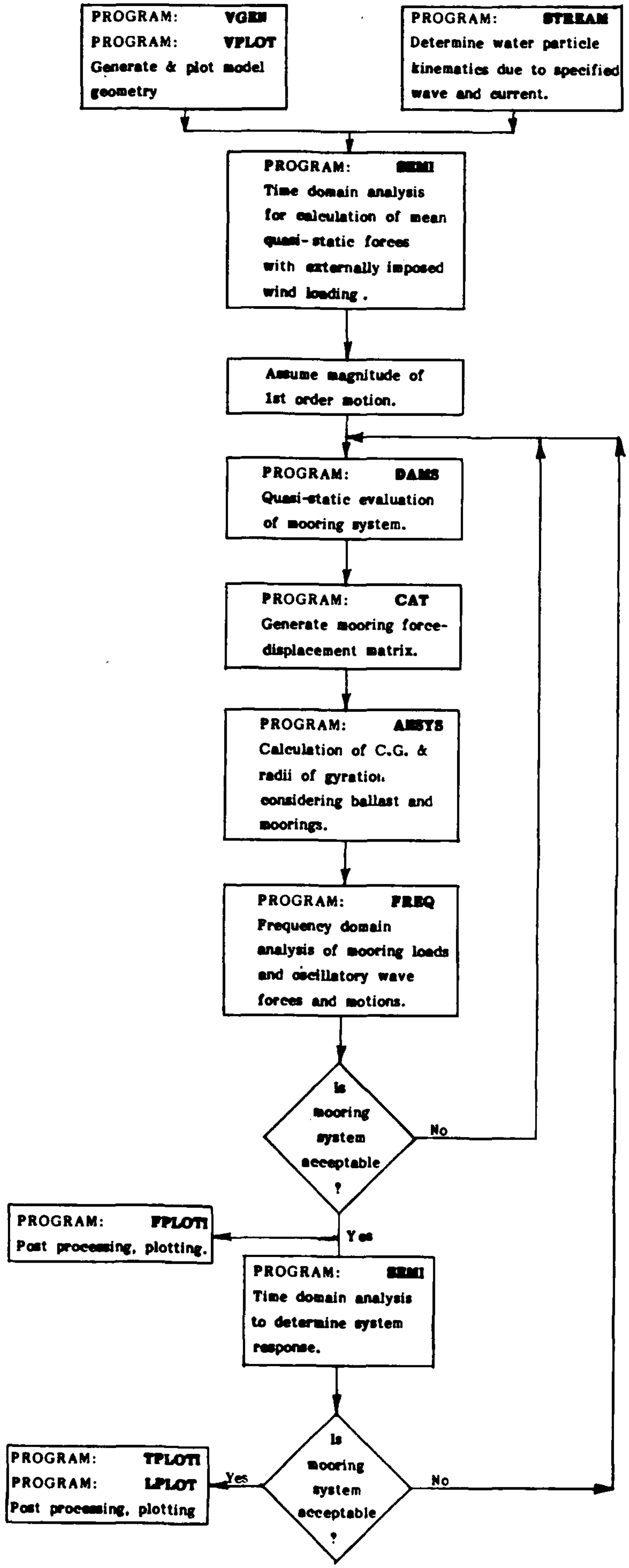
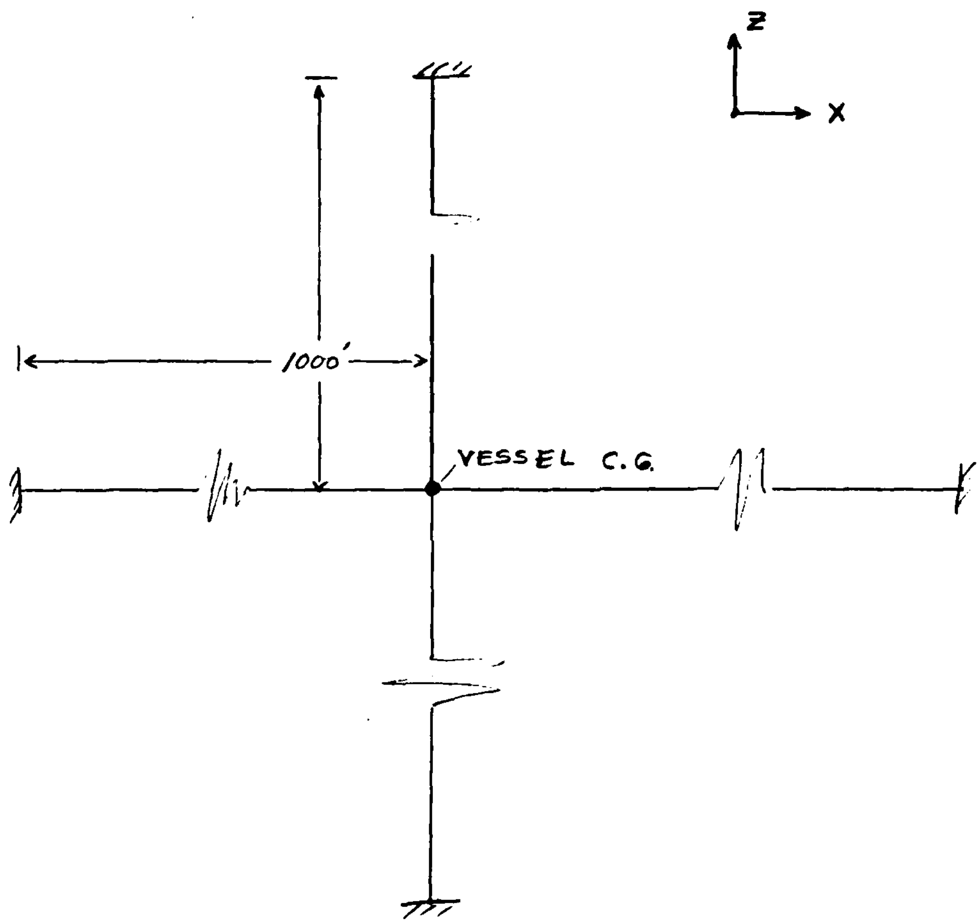


Figure 2.1 Simulation Cycle

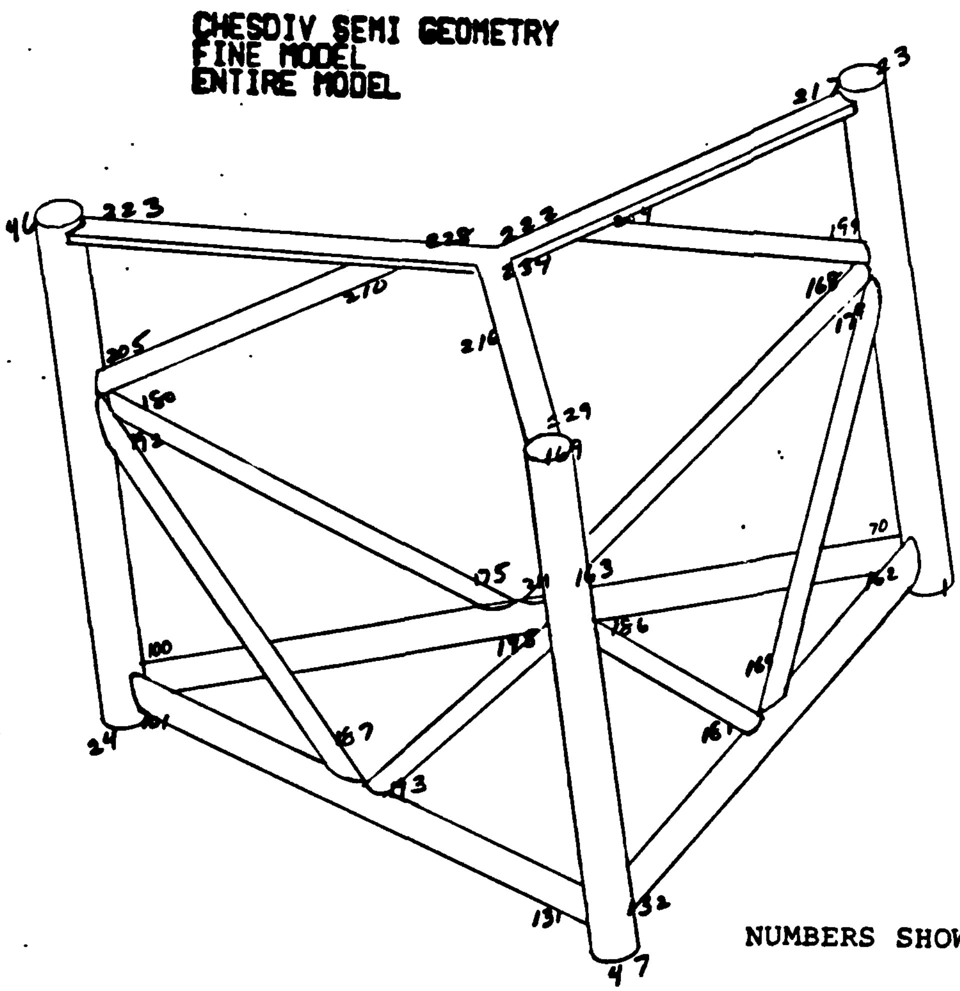
BRIAN WATT ASSOCIATES, INC. CONSULTING ENGINEERS HOUSTON, TEXAS	CLIENT: PROJECT:	FILING CODE: JOB NO. 210 PAGE OF
SYSTEM:		ORIGINATOR: R. A. DATE:
CALCULATION FOR:		REVIEWER: DATE:
		REVISION:
		RESULTS:



K = 10,000 lb/ft

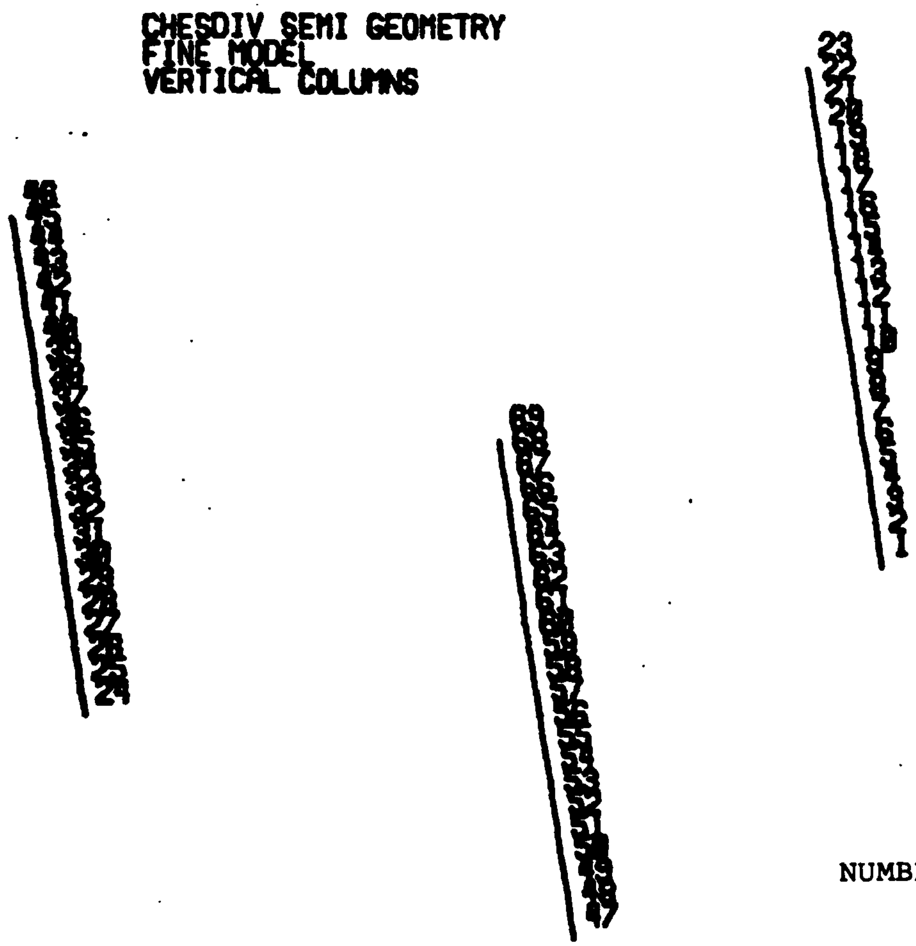
FIGURE 2.2 - MEAN FORCE ANALYSIS

FILING CODE:



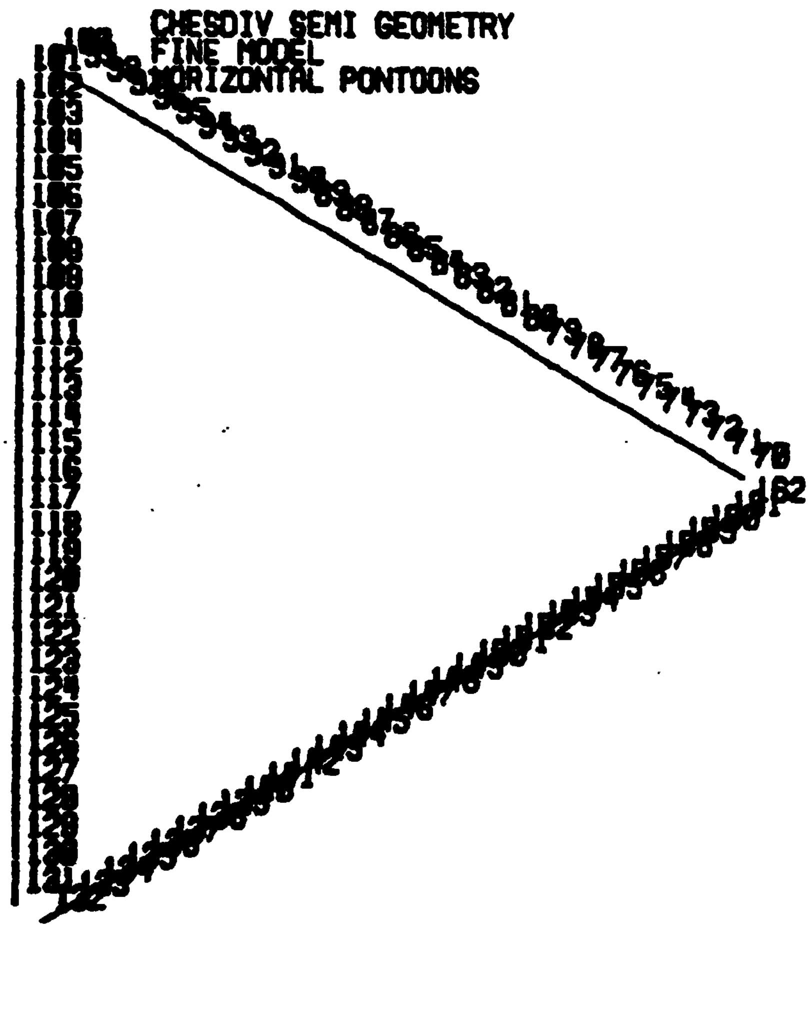
NUMBERS SHOWN ARE NODES

FIGURE 2.3



NUMBERS SHOWN ARE NODES

FIGURE 2.4



NUMBERS SHOWN ARE NODES

FIGURE 2.5

CHESDIV SEMI GEOMETRY
FINE MODEL
LOWER BRACES

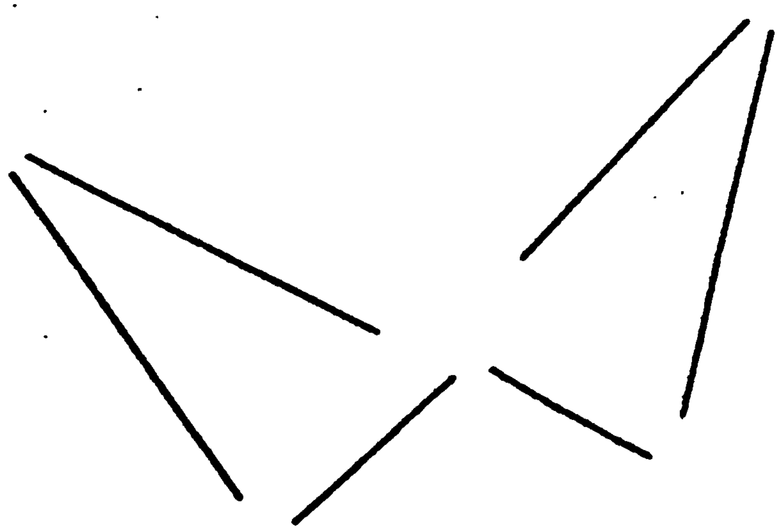


FIGURE 2.6

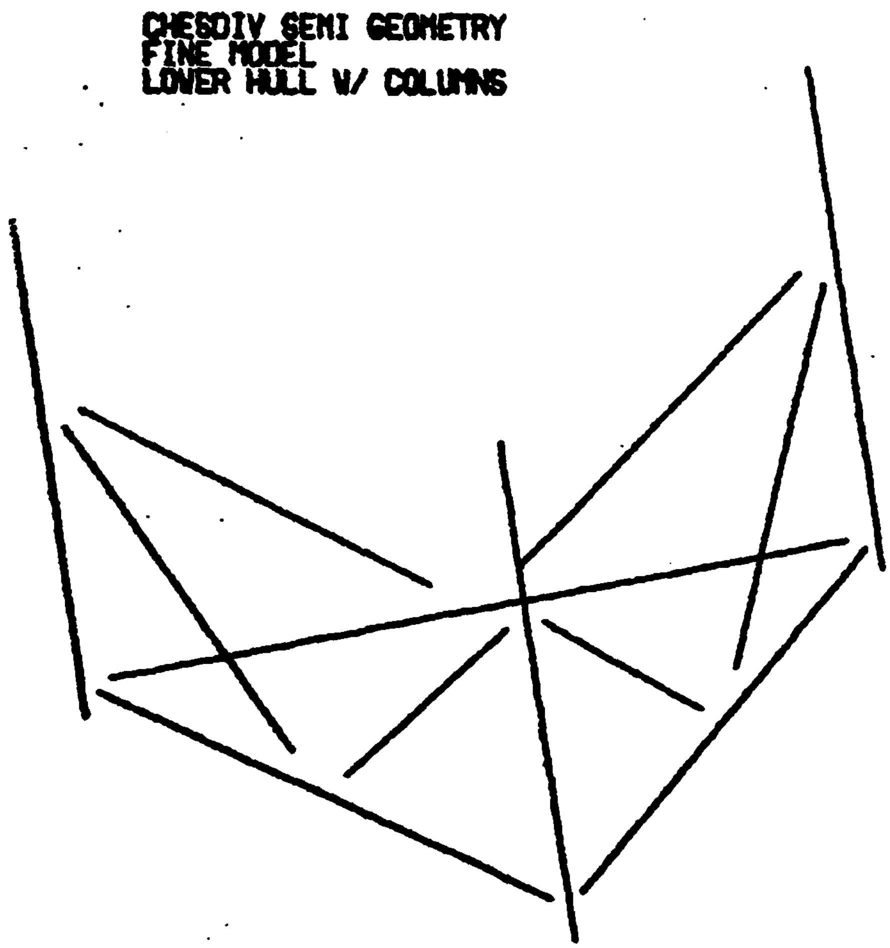


FIGURE 2.7

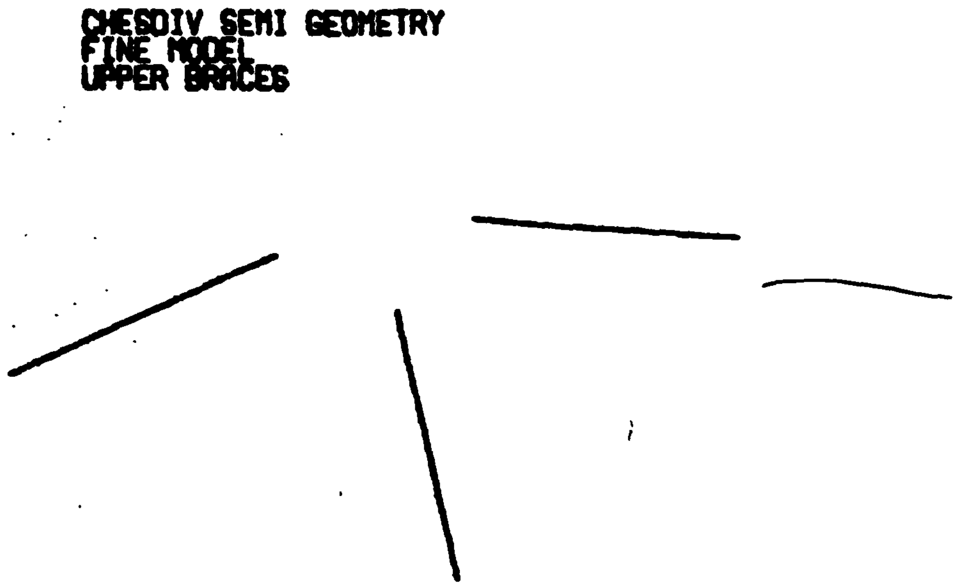
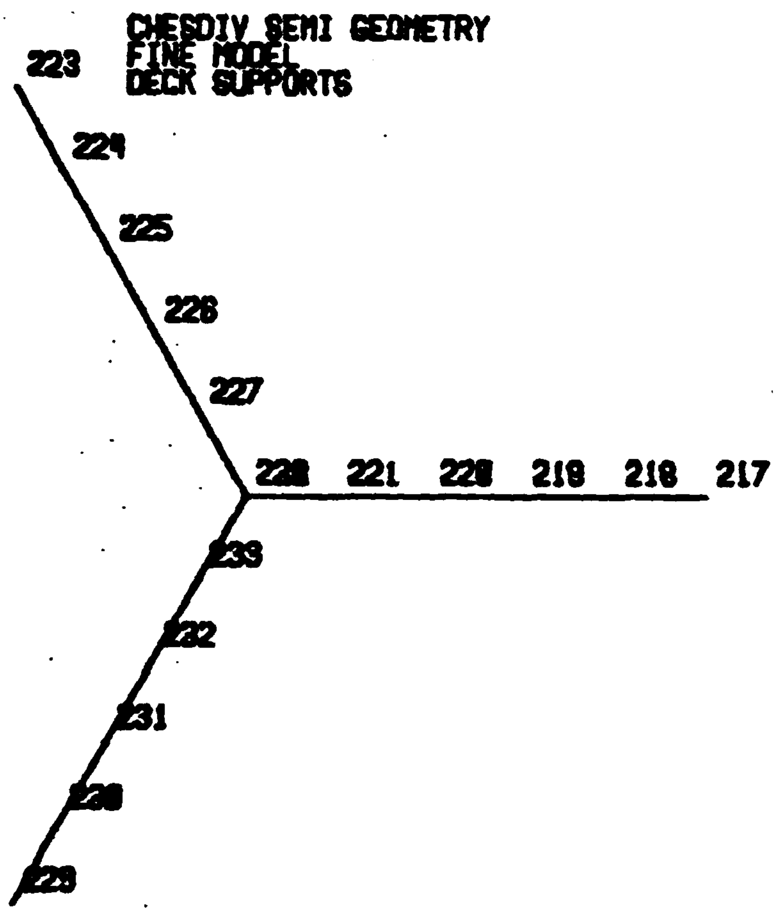


FIGURE 2.8



NUMBERS SHOWN ARE NODES

FIGURE 2.9

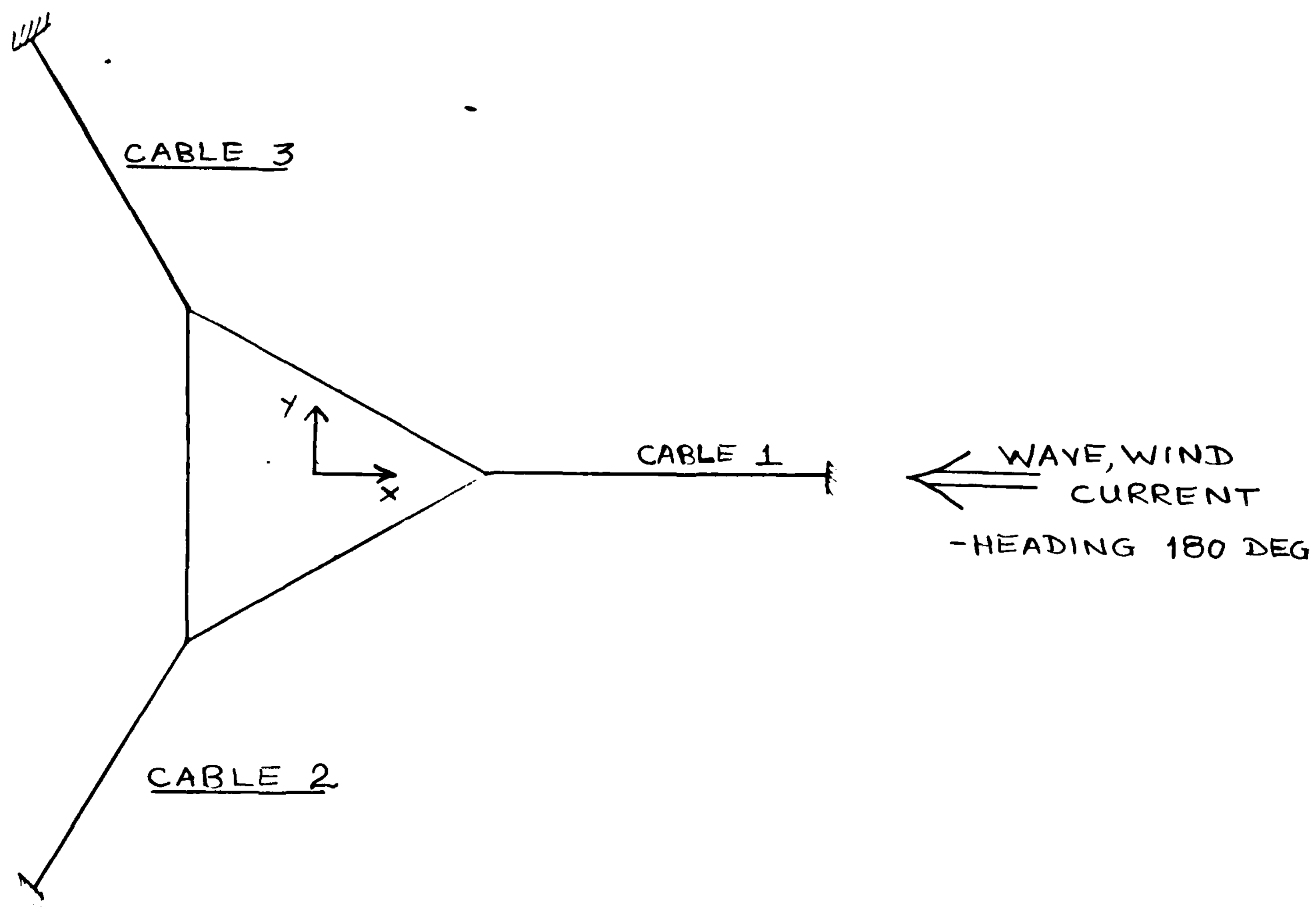


FIGURE 2.10 PLAN VIEW AND CO-ORDINATE SYSTEM

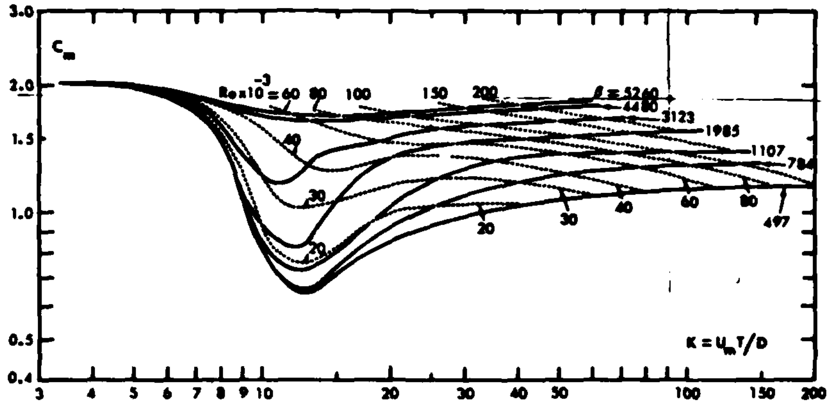


Fig. 3.20. C_m versus K for various values of the Reynolds number and the frequency parameter (Sarpkaya 1976a).

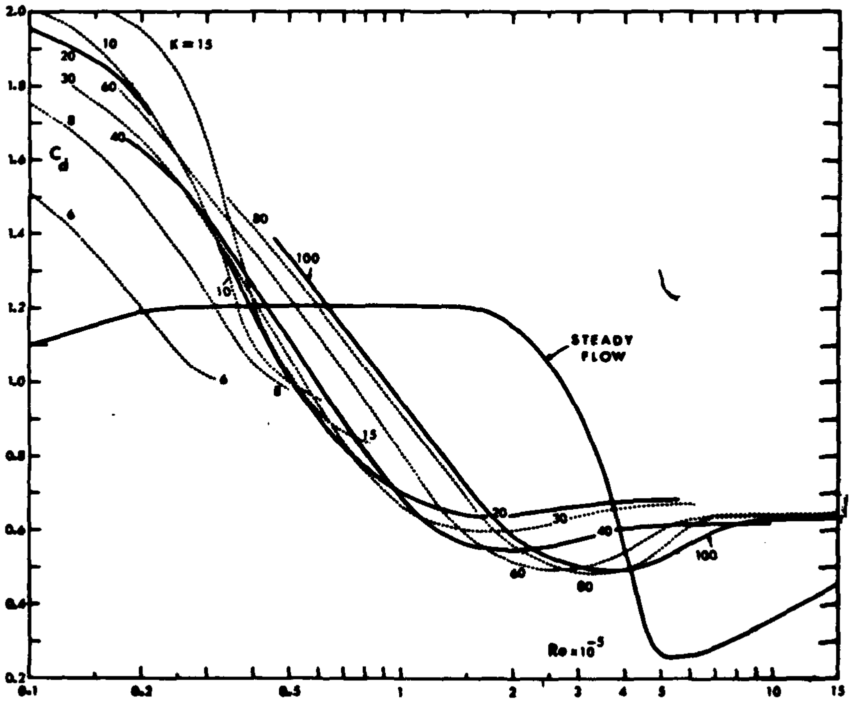


Fig. 3.21. C_d versus Reynolds number for various values of K (Sarpkaya 1976a).

REF.- "MECHANICS OF WAVE FORCES ON OFFSHORE STRUCTURES" - TURGUT SARPKAYA, MICHAEL ISAACSON.

FIGURE 2-11 VARIATION IN C_D & C_M

BRIAN WATT ASSOCIATES, INC. CONSULTING ENGINEERS HOUSTON, TEXAS	CLIENT: U. S. NAVY	FILING CODE:
	PROJECT:	JOB NO. 210
		PAGE 1 OF 3
SYSTEM: SEMISUBMERSIBLE INSTRUMENT PLATFORM		ORIGINATOR: R. Ay DATE: 8/83
CALCULATION FOR: WIND FORCES		REVIEWER: DATE:
		REVISION:
		RESULTS:

$\rho_{air} = .0024 \ \frac{slugs}{ft^3}$ @ 60°F

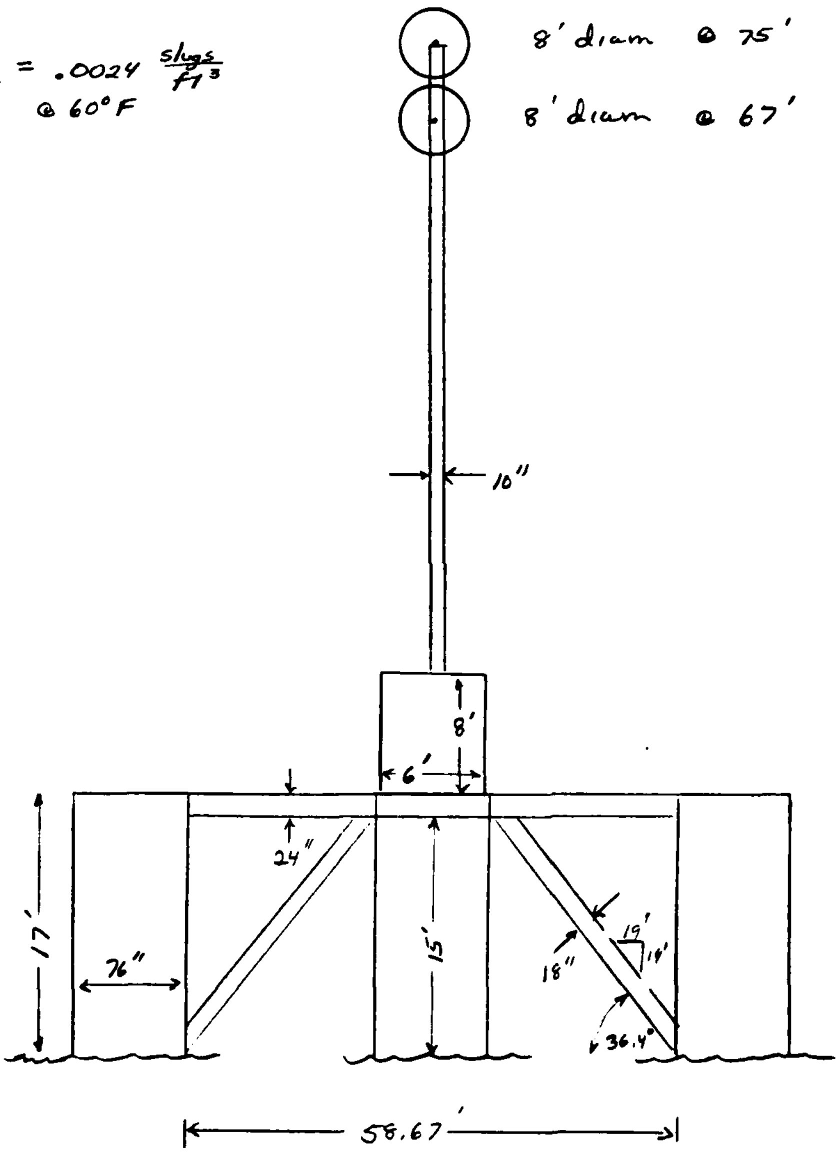
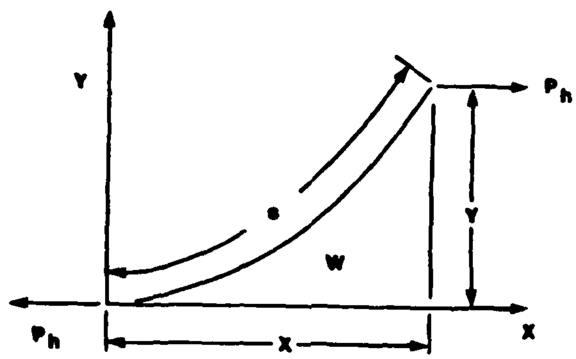


FIGURE 2.12 SEMISUBMERSIBLE PROJECTED AREA

FILING CODE:



$$(Y+P_h/W)^2 = s^2 + (P_h/W)^2$$

$$Y = (P_h/W)(\cosh(WX/P_h)-1)$$

$$s = (P_h/W)\sinh(WX/P_h)$$

FIG. 2.13 BASIC CATENARY RELATIONSHIPS

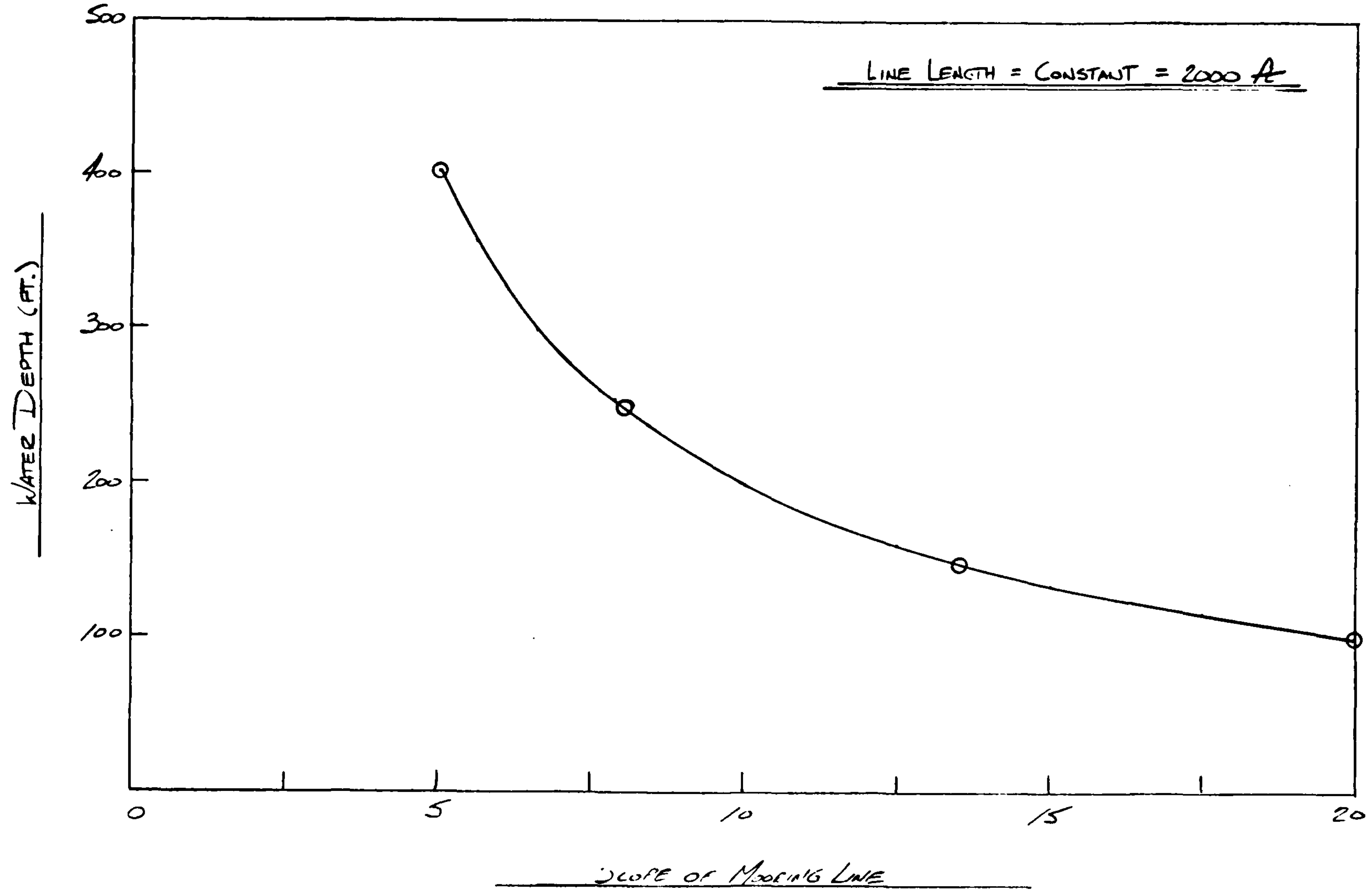
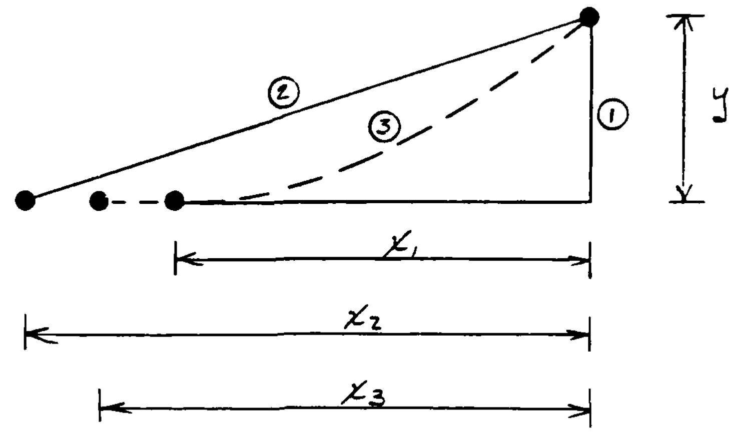


FIGURE 2.14 ASSUMED SCOPE - WATER DEPTH RELATIONSHIP



① TOTALLY SLACK CONDITION : $x_1 = x_{min}$

② TOTALLY TAUT CONDITION : $x_2 = x_{max}$

③ TRIAL LOCATION FOR SIZE SELECTION : x_3

D = 112'

x	y
1903	97
1997.6	97
1950.3	97

D = 162'

x	y
1853	147
1994.6	147
1923.8	147

D = 262'

x	y
1753	247
1984.7	247
1868.8	247

D = 412'

x	y
1603	397
1900.2	397
1781.6	397

FIGURE 2.15 DTA vs DEPTH

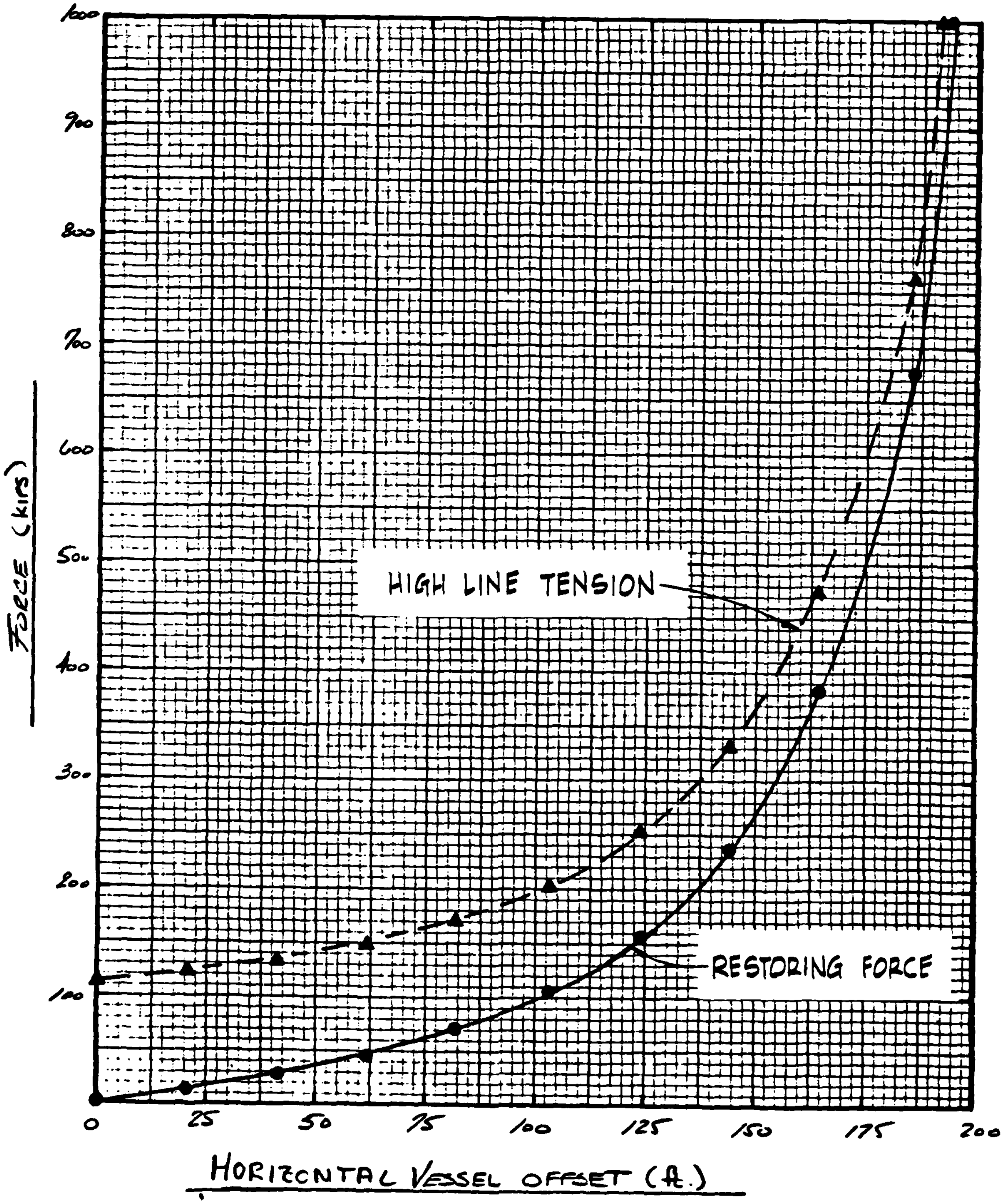


FIGURE 3.1 MOORING SYSTEM CHARACTERISTICS AT D = 412 ft

210/.12
262'

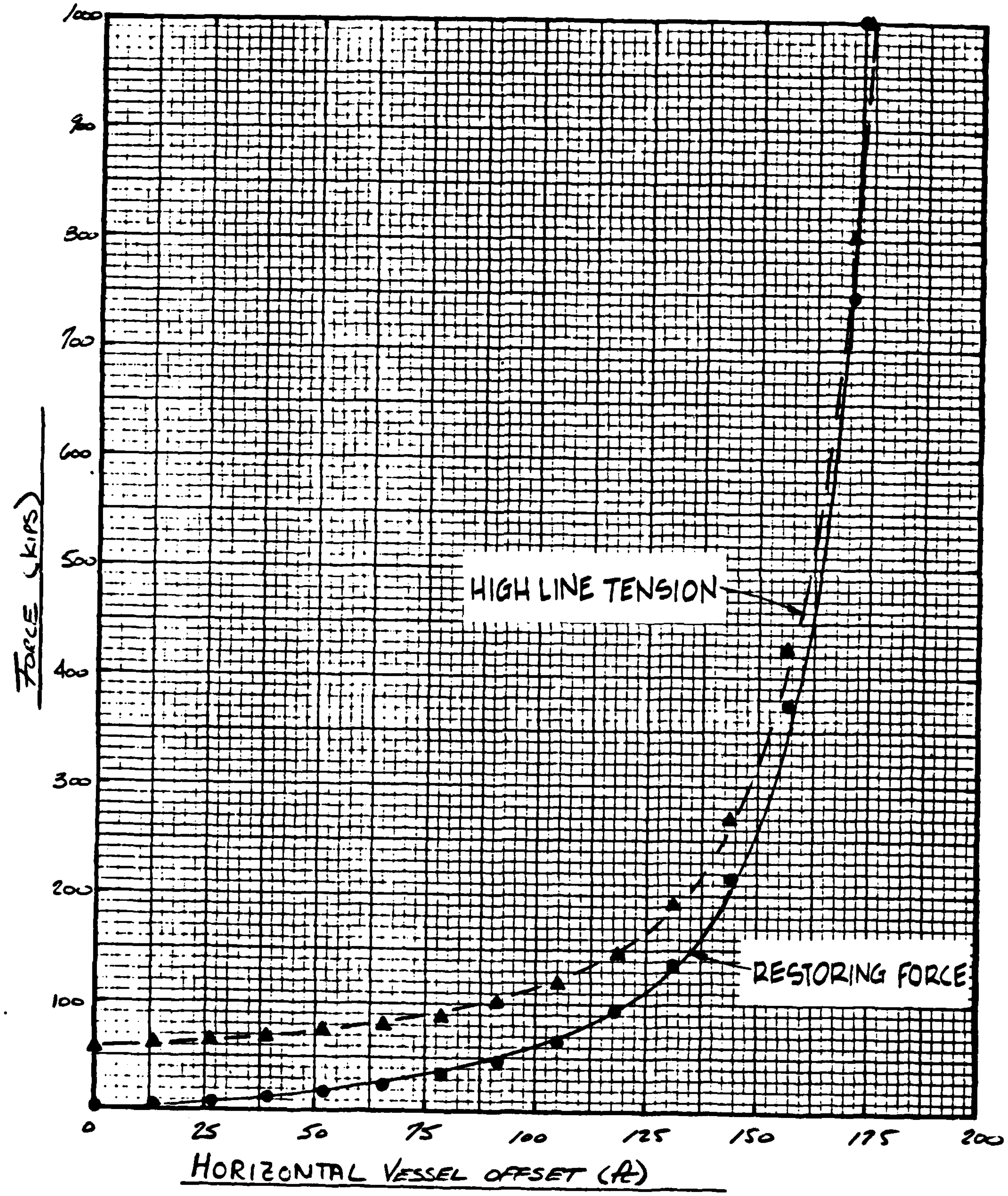


FIGURE 3.2 MOORING SYSTEM CHARACTERISTICS AT D = 262 ft

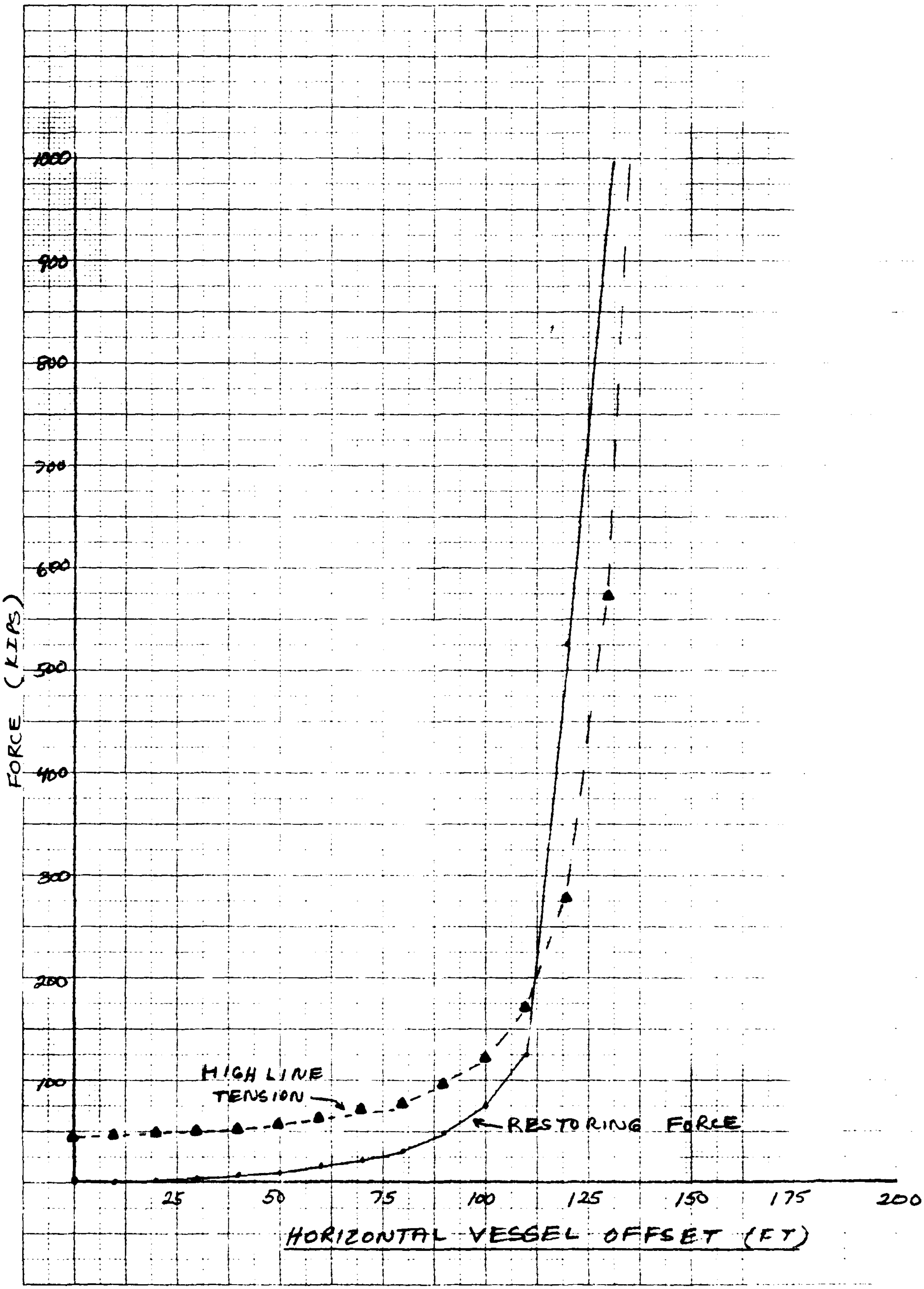


FIGURE 3.3 MOORING SYSTEM CHARACTERISTICS AT D= 165 FT

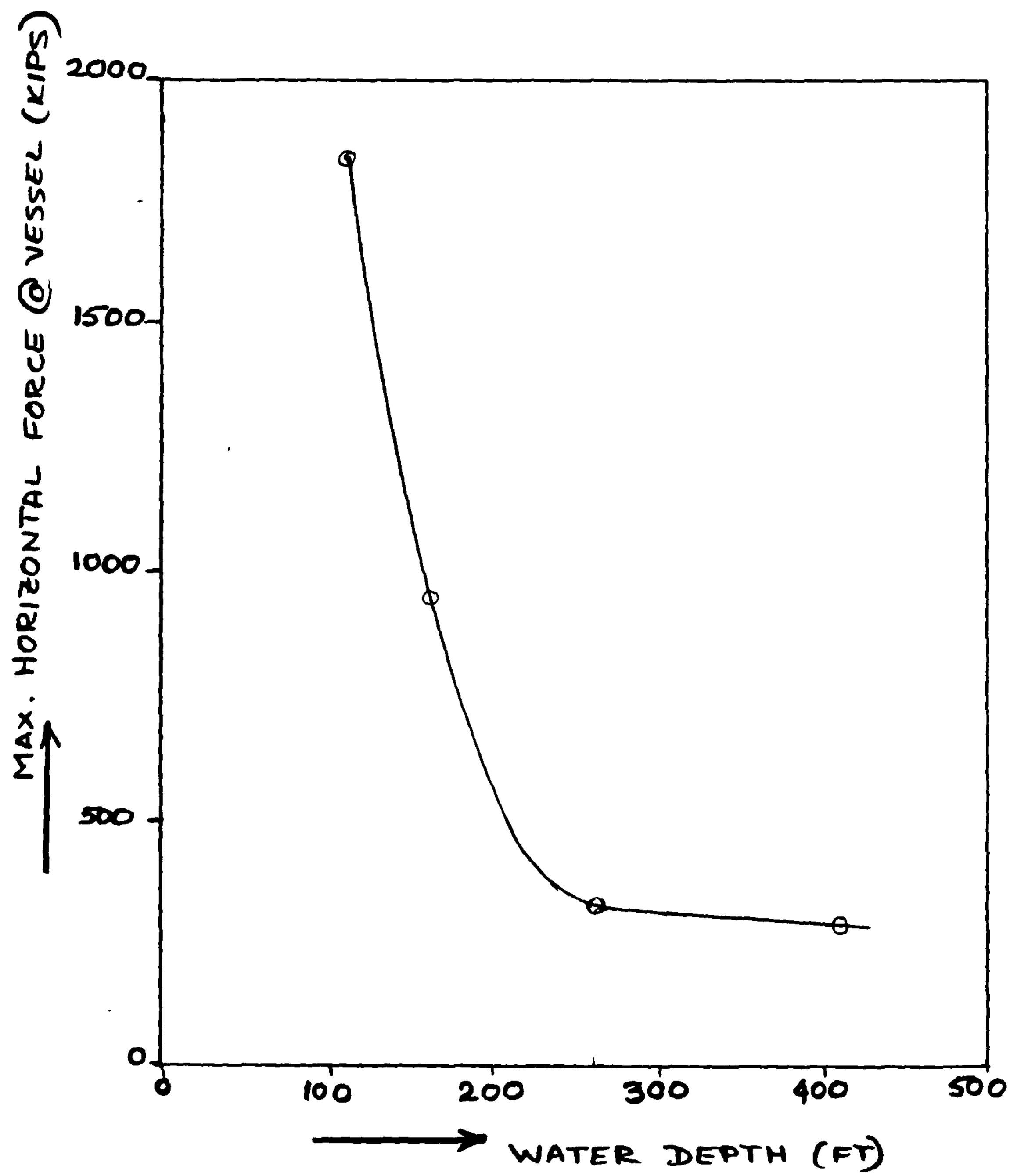


FIGURE 3.4 PEAK HORIZONTAL FORCE @ VESSEL AGAINST WATER DEPTH

ENGINEERING ANALYSIS OF OCEAN

ENGINEERING PROJECTS

TASK 1 MOORING SYSTEM DESIGN AND TIME DOMAIN SIMULATION

OF A SEMISUBMERSIBLE BUOY

APPENDIX A

- FREQUENCY DOMAIN RESULTS
- TIME HISTORY PLOTS
- SUMMARY OF RESULTS
- PROPOSED MOORING SYSTEM

APPENDIX A.1

WATER DEPTH	=	400 FT
EFFECTIVE DEPTH	=	412 FT
WAVE HEIGHT	=	84 FT
WAVE PERIOD	=	14.6 SEC
CURRENT	=	3 KN
WIND	=	150 KN
MOORING CHAIN	=	5 IN

ITEM	WEIGHT (S. TONS)
SEMISUBMERSIBLE + PAYLOAD	65.1
MOORING SYSTEM VERTICAL COMPONENT	164.2
BALLAST	23.7
TOTAL DISPLACEMENT	253.0

SEMISUBMERSIBLE WEIGHT DISTRIBUTION

DEPTH = 412 FT

FREQUENCY DOMAIN RESULTS

UNITS : LBS , FEET

```
**** CALCULATED DISPLACEMENT PROPERTIES ****

DISPLACEMENT                              =     0.49987E 06
CENTER OF BUOYANCY ALONG X-AXIS           =       0.00
CENTER OF BUOYANCY ALONG Y-AXIS           =       0.00
CENTER OF BUOYANCY ALONG Z-AXIS           =     -19.89

**** STRUCTURAL INPUT PROPERTIES ****

STRUCTURAL WEIGHT                         =     0.17768E 06
ROLL  RADIUS OF GYRATION                  =      26.90
PITCH RADIUS OF GRYRATION                 =      26.90
YAW   RADIUS OF GRYRATION                 =      31.50
CENTER OF GRAVITY ALONG X-AXIS            =       0.00
CENTER OF GRAVITY ALONG Y-AXIS            =       0.00
CENTER OF GRAVITY ALONG Z-AXIS            =     -12.90

**** WATER INPUT PROPERTIES ****

MASS DENSITY OF WATER                     =       1.99
ACCELERATION OF GRAVITY                   =      32.17
WAVE HEIGHT                               =      84.00
WAVE PERIOD                               =      14.60
WATER DEPTH                               =     412.00
ANGLE OF ATTACK IN DEGREES                =     180.00

**** CALCULATED WATERPLANE PROPERTIES ****

WATERPLANE AREA                           =      94.51
CENTER OF AREA ALONG X-AXIS               =       0.00
CENTER OF AREA ALONG Y-AXIS               =      -0.00
WATERPLANE INERTIA ABOUT X-AXIS           =     0.66787E 05
WATERPLANE INERTIA ABOUT Y-AXIS           =     0.66783E 05
METACENTRIC HEIGHT IN ROLL                =       1.57
METACENTRIC HEIGHT IN PITCH               =       1.57

**** CENTERS ARE IN ORIGINAL SYSTEM ****

**** INERTIAS ARE ABOUT AXES THRU CG ***
```

BODY MASS MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.55224716E 04	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00
SWAY	0.00000000E 00	0.55224716E 04	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00
HEAVE	0.00000000E 00	0.00000000E 00	0.55224716E 04	0.00000000E 00	0.00000000E 00	0.00000000E 00
ROLL	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.39961156E 07	0.00000000E 00	0.00000000E 00
PITCH	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.39961156E 07	0.00000000E 00
YAW	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.54796724E 07

ADDED MASS MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.96193757E 04	-0.20929747E-09	-0.64801498E-11	-0.22882887E-08	-0.48943715E 05	0.24875956E-01
SWAY	-0.20929747E-09	0.96179669E 04	-0.34106051E-11	0.48927996E 05	-0.22973836E-08	0.22230983E 02
HEAVE	-0.64801498E-11	-0.34106051E-11	0.12226625E 05	0.24875950E-01	-0.31666512E 02	-0.13096724E-09
ROLL	-0.22882887E-08	0.48927996E 05	0.24875950E-01	0.50137260E 07	-0.69180543E 00	0.54602375E 02
PITCH	-0.48943715E 05	-0.22973836E-08	-0.31666512E 02	-0.69180543E 00	0.50131609E 07	-0.27819544E 00
YAW	0.24875956E-01	0.22230983E 02	-0.13096724E-09	0.54602375E 02	-0.27819546E 00	0.95184866E 07

HYDROSTATIC STIFFNESS MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00
SWAY	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00
HEAVE	0.00000000E 00	0.00000000E 00	0.60525515E 04	-0.46596940E-09	-0.20175172E 02	0.00000000E 00
ROLL	0.00000000E 00	0.00000000E 00	-0.46596940E-09	0.78283207E 06	-0.15532313E-11	0.00000000E 00
PITCH	0.00000000E 00	0.00000000E 00	-0.20175172E 02	-0.15532313E-11	0.78258210E 06	0.00000000E 00
YAW	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00

MOORING STIFFNESS MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.98947201E 03	-0.45474735E-12	0.22145101E 03	-0.29103830E-10	0.20888841E 05	0.43655746E-10
SWAY	-0.45474735E-12	0.23322553E 03	-0.45474735E-12	-0.10178762E 05	-0.72759576E-11	0.76902283E 04
HEAVE	0.22145101E 03	-0.45474735E-12	0.13884000E 04	-0.58207661E-10	-0.46965979E 03	0.72759576E-10
ROLL	-0.29103830E-10	-0.10178762E 05	-0.58207661E-10	0.11059359E 07	-0.37252903E-08	-0.41766163E 06
PITCH	0.20888841E 05	-0.72759576E-11	-0.46965979E 03	-0.37252903E-08	0.10575755E 07	0.00000000E 00
YAW	0.43655746E-10	0.76902283E 04	0.72759576E-10	-0.41766163E 06	0.00000000E 00	0.38444306E 06

MODE SHAPE MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.99929602E 00	-0.33134545E-08	0.47078384E-01	-0.19669218E-05	0.99473651E 00	0.13194027E-06
SWAY	-0.45116535E-07	0.99974382E 00	0.30463141E-07	-0.98942727E 00	-0.71327175E-06	0.99869026E 00
HEAVE	-0.34120189E-01	0.10865334E-09	0.99889091E 00	0.36024551E-06	-0.59170865E-01	-0.26348131E-08
ROLL	-0.12853671E-08	0.48477226E-03	-0.59733923E-08	0.14339969E 00	0.10730733E-06	0.18837151E-01
PITCH	-0.15597536E-01	0.50422113E-10	0.75940206E-03	-0.16110718E-06	0.83654516E-01	-0.22260655E-08
YAW	-0.43334171E-08	-0.22628540E-01	0.39345939E-09	-0.21684317E-01	-0.15200483E-07	0.47570135E-01

NATURAL PERIOD IN SURGE= 0.30942089E 02
NATURAL PERIOD IN SWAY = 0.10506922E 03
NATURAL PERIOD IN HEAVE= 0.96975036E 01
NATURAL PERIOD IN ROLL = 0.13011823E 02
NATURAL PERIOD IN PITCH= 0.12620198E 02
NATURAL PERIOD IN YAW = 0.39448139E 02

PERIOD	LENGTH	SURGE	PHASE	SWAY	PHASE	HEAVE	PHASE	ROLL	PHASE	PITCH	PHASE	YAW	PHASE
14.60	1074.06	0.9331	56.74	0.0000	-54.44	0.8516	-158.85	0.00000	96.09	0.12430	-126.94	0.00000	-46.06

WAVE PERIOD= 14.60

	INERTIAL FORCES		FROUDE-KRYLOV FORCES		VICOUS DRAG FORCES	
	AMPLITUDE	PHASE SHIFT	AMPLITUDE	PHASE SHIFT	AMPLITUDE	PHASE SHIFT
SURGE	0.67791267E 05	0.91409616E 02	0.10646730E 06	0.90080291E 02	0.41205758E 06	-0.17889870E 03
SWAY	0.75054505E-03	-0.76933207E 01	0.83393115E-03	-0.76936417E 01	0.47955827E-02	0.81587735E 02
HEAVE	0.82284033E 05	-0.17999990E 03	0.16633086E 06	0.32214386E-01	0.64520503E 06	-0.89216015E 02
ROLL	0.15925629E 00	0.17059448E 03	0.17695184E 00	0.17059448E 03	0.58628841E 00	-0.10232531E 03
PITCH	0.48451025E 06	-0.88189424E 02	0.88702257E 05	0.57556102E 02	0.28829626E 07	-0.11456898E 02
YAW	0.17086936E 00	0.79383861E 02	0.18985463E 00	0.79384087E 02	0.10310228E 01	0.16838210E 03

DAMPING MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.25217961E 05	-0.54328161E-05	-0.27365266E 03	0.27298316E-03	-0.10318426E 06	0.64551203E-01
SWAY	-0.54328161E-05	0.22582778E 05	-0.12630303E-04	0.78845596E 05	0.15740938E-03	0.17441896E 05
HEAVE	-0.27365266E 03	-0.12630303E-04	0.40971758E 05	0.40472737E-01	0.45655006E 05	-0.43040392E-03
ROLL	0.27298316E-03	0.78845596E 05	0.40472737E-01	0.16132955E 08	-0.13943393E 01	0.20268899E 06
PITCH	-0.10318426E 06	0.15740938E-03	0.45655006E 05	-0.13943394E 01	0.16374054E 08	-0.73644863E 00
YAW	0.64551203E-01	0.17441896E 05	-0.43040392E-03	0.20268899E 06	-0.73644867E 00	0.21721920E 08

CATENARY MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.99005532E 03	-0.45474735E-12	0.22151984E 03	-0.58207661E-10	0.20889345E 05	0.43655746E-10
SWAY	-0.45474735E-12	0.23190413E 03	-0.45474735E-12	-0.10170338E 05	-0.72759576E-11	0.77007045E 04
HEAVE	0.22151984E 03	-0.45474735E-12	0.13884000E 04	-0.17462298E-09	-0.46964873E 03	0.43655746E-10
ROLL	-0.58207661E-10	-0.10170338E 05	-0.17462298E-09	0.11058839E 07	-0.37252903E-08	-0.41754427E 06
PITCH	0.20889345E 05	-0.72759576E-11	-0.46964873E 03	-0.37252903E-08	0.10575672E 07	0.00000000E 00
YAW	0.43655746E-10	0.77007045E 04	0.43655746E-10	-0.41754427E 06	0.00000000E 00	0.38401132E 06

MOORING SYSTEM USED : 5" GRADE 2 CHAIN

LENGTH = 2000 FT

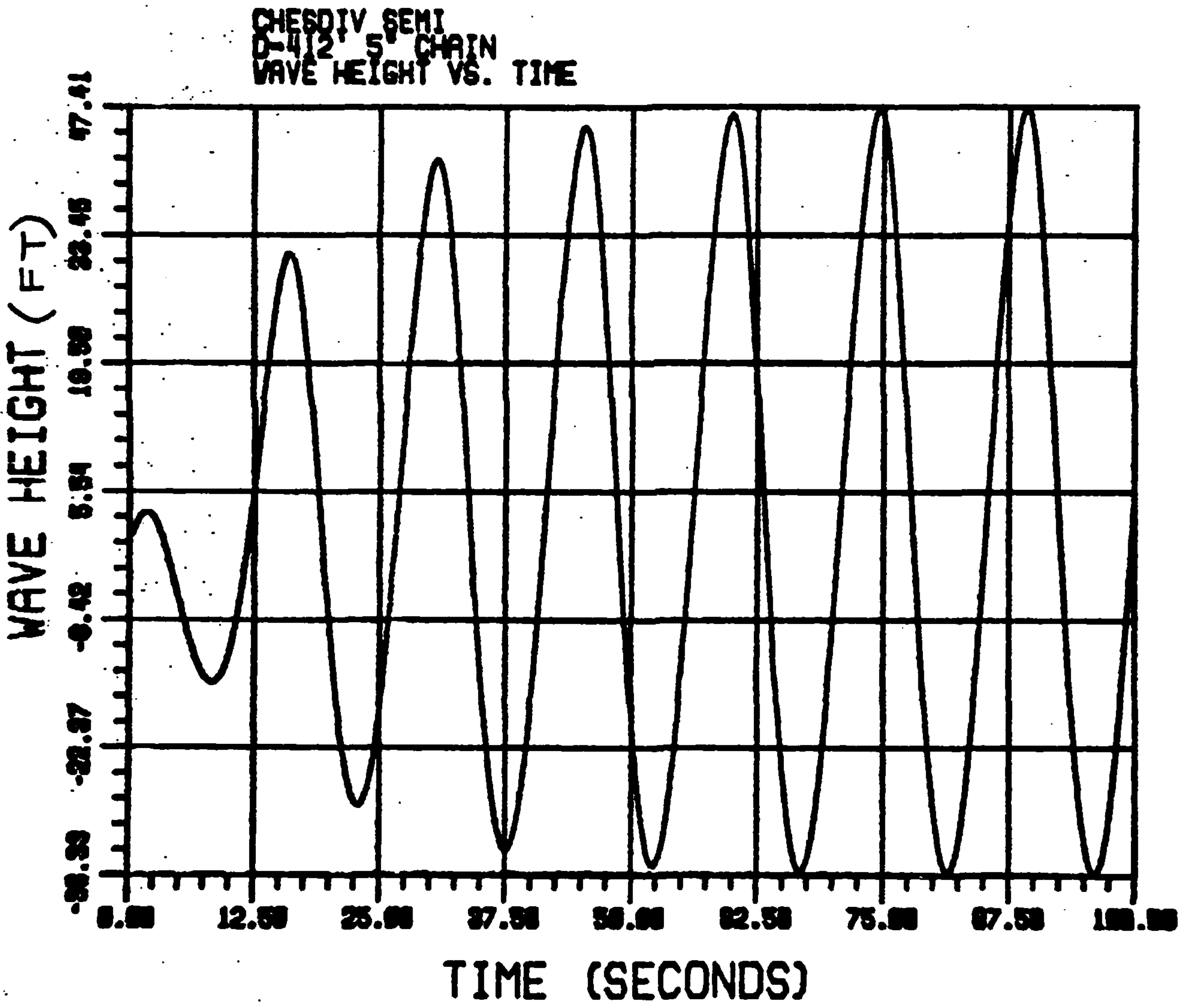
LOCATION OF ANCHOR = 1750 FT

FORCES IN CATENARY LINES

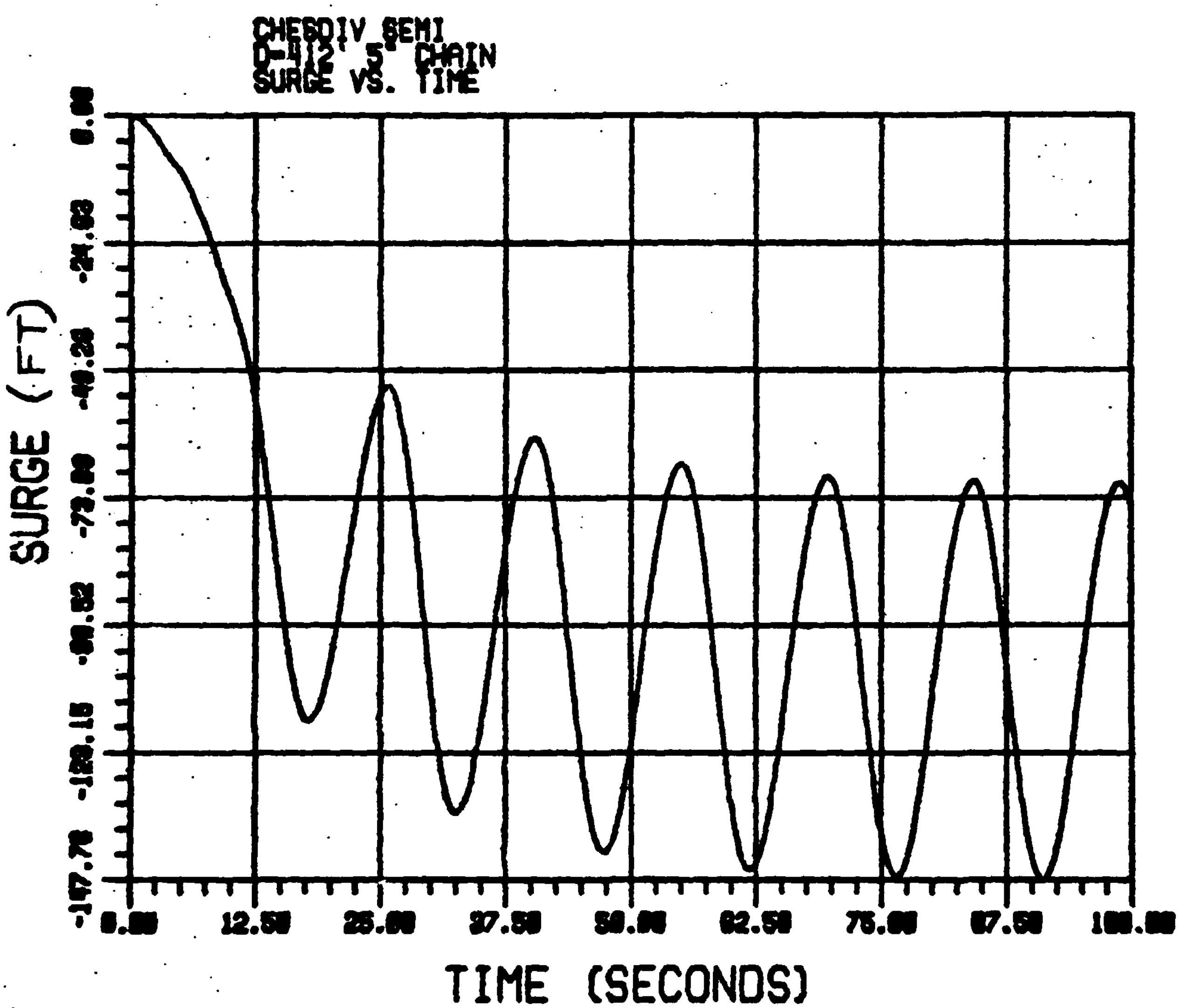
PERIOD	ELEMENT	MIN HOR FOR AT SHP MAX HOR FOR AT SHP	MIN VER FOR AT SHP MAX VER FOR AT SHP	MIN TEN AT SHP MAX TEN AT SHP	MIN HOR FOR AT BOT MAX HOR FOR AT BOT	MIN VER FOR AT BOT MAX VER FOR AT BOT
14.60	1	0.65430474E 05	0.13050363E 06	0.14605236E 06	0.00000000E 00	0.00000000E 00
		0.32608722E 06	0.26121349E 06	0.41781020E 06	0.18821018E 06	0.00000000E 00
14.60	2	0.19725598E 04	0.81272135E 05	0.81297260E 05	0.00000000E 00	0.00000000E 00
		0.59869451E 04	0.99616816E 05	0.99738919E 05	0.00000000E 00	0.00000000E 00
14.60	3	0.19725599E 04	0.81272134E 05	0.81297260E 05	0.00000000E 00	0.00000000E 00
		0.59869441E 04	0.99616815E 05	0.99738919E 05	0.00000000E 00	0.00000000E 00

FORCES AT ANCHOR

FORCES IN LBS.



BRIAN WATT ASSOCIATES, INC.



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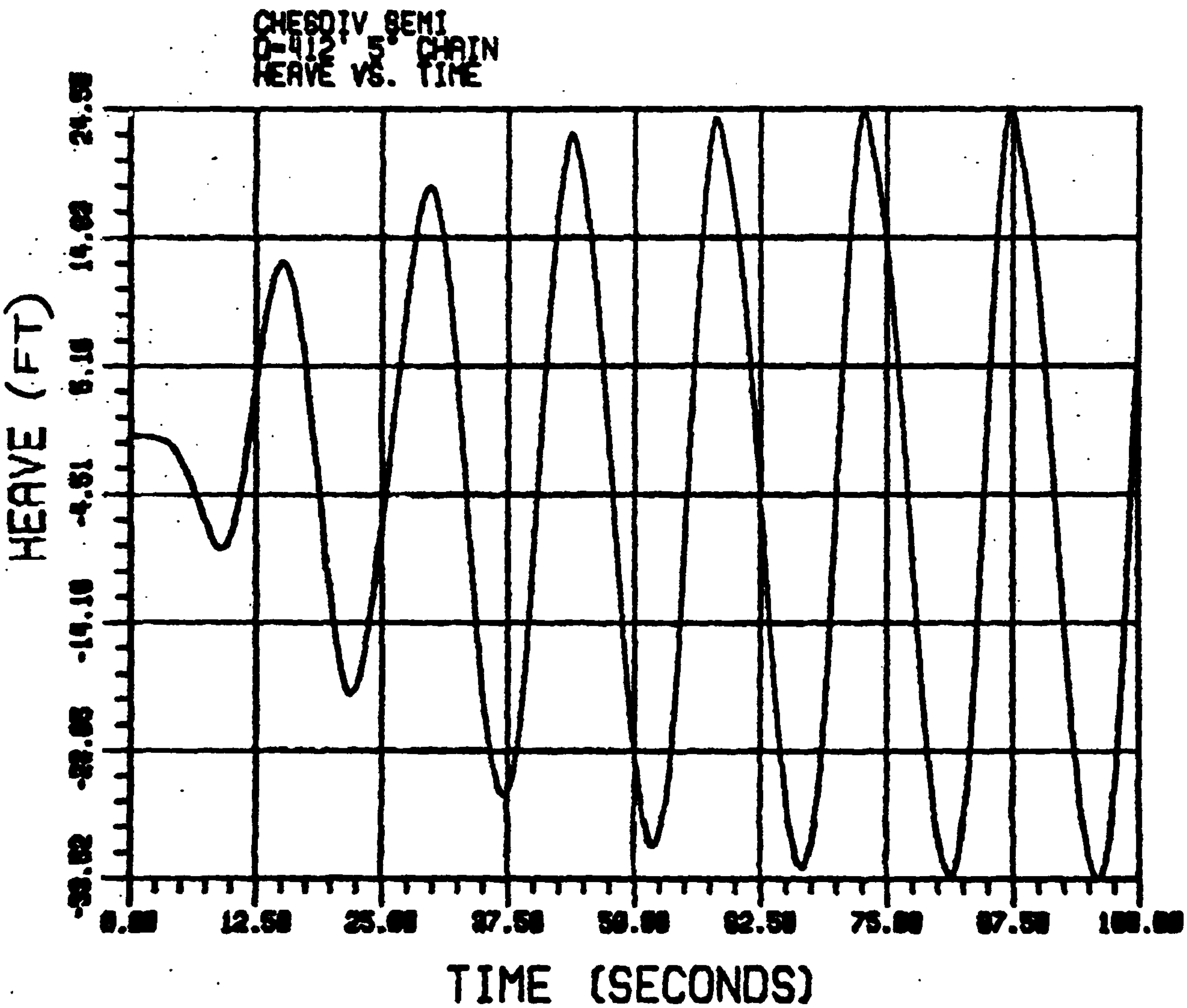
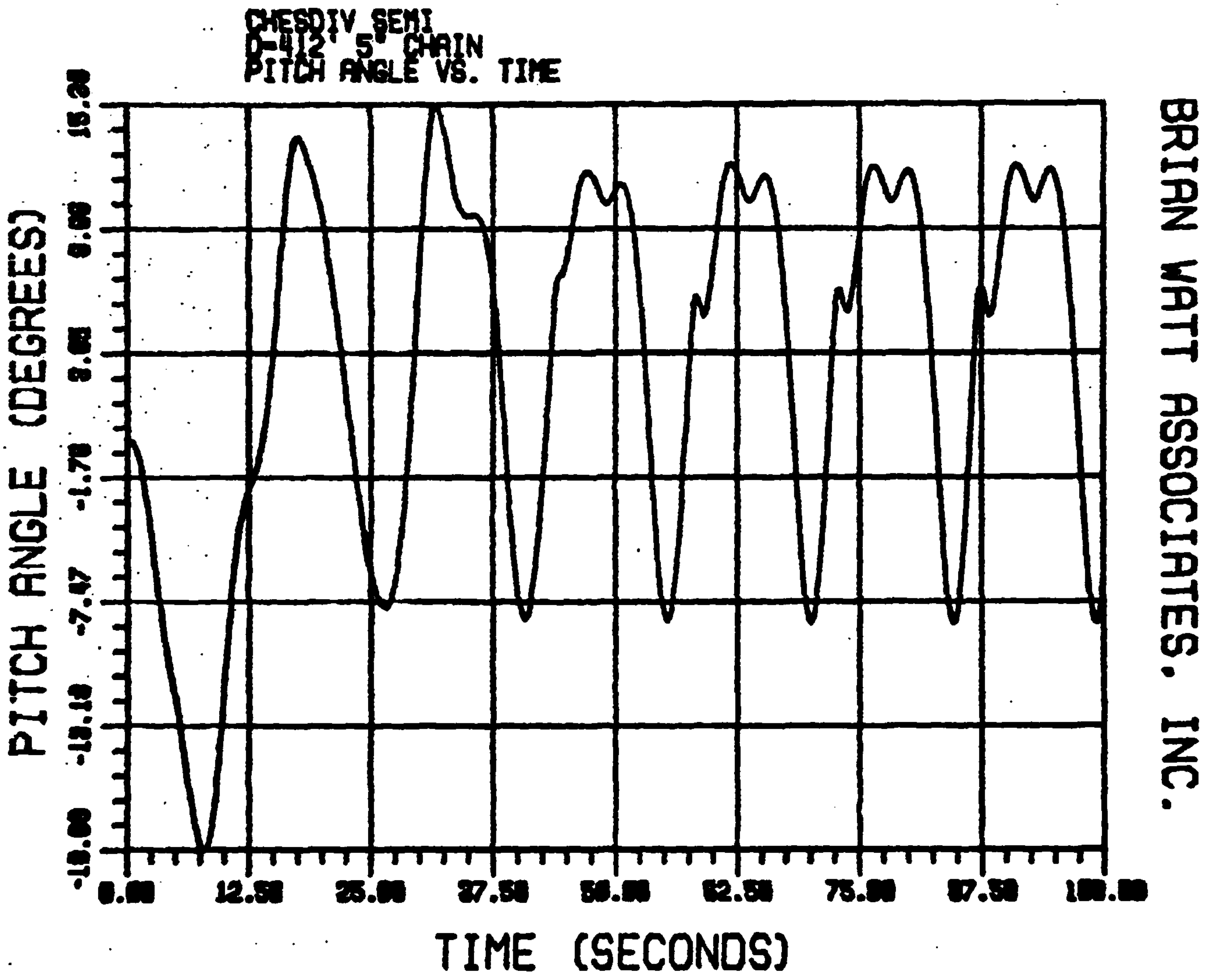
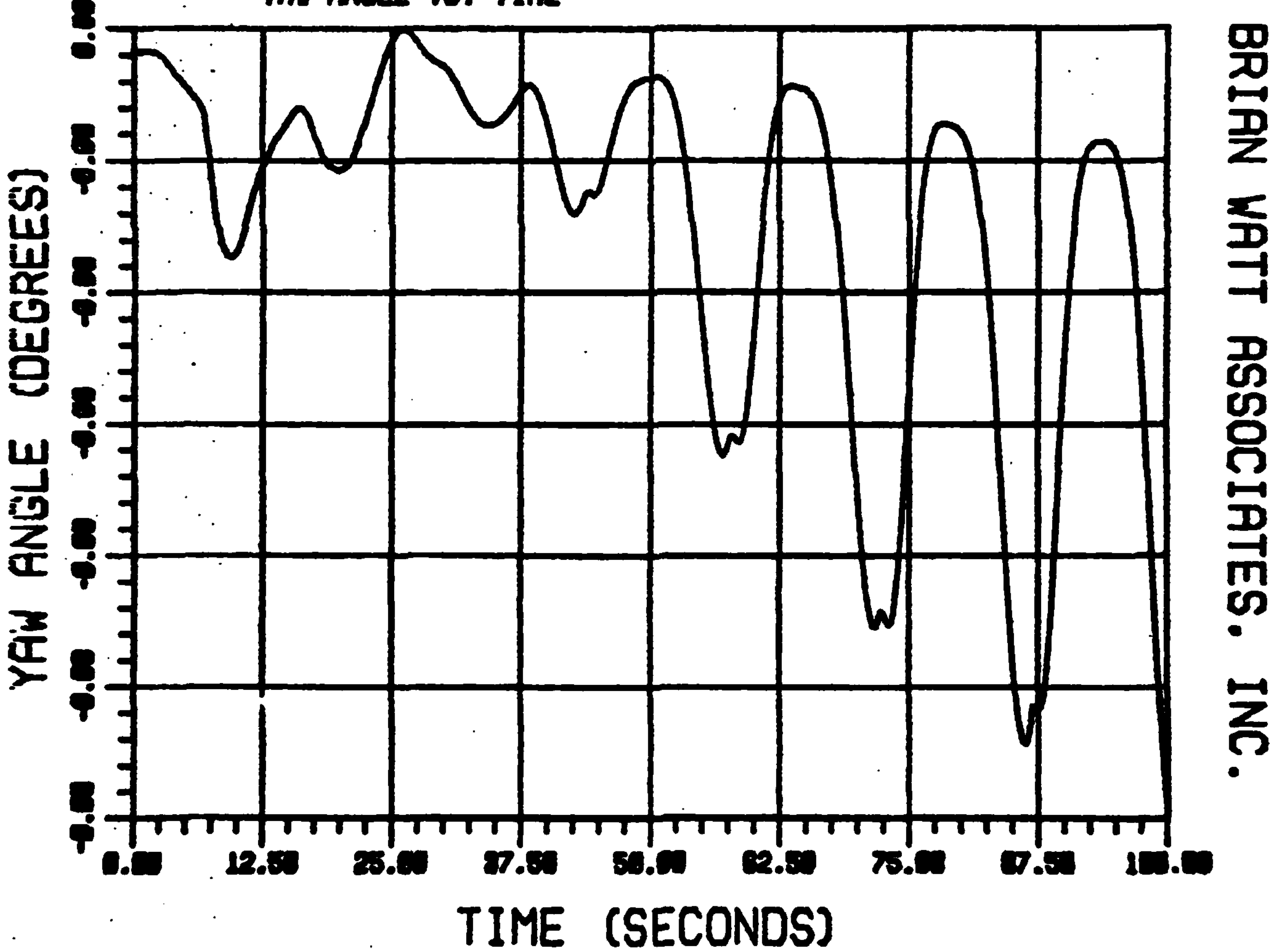
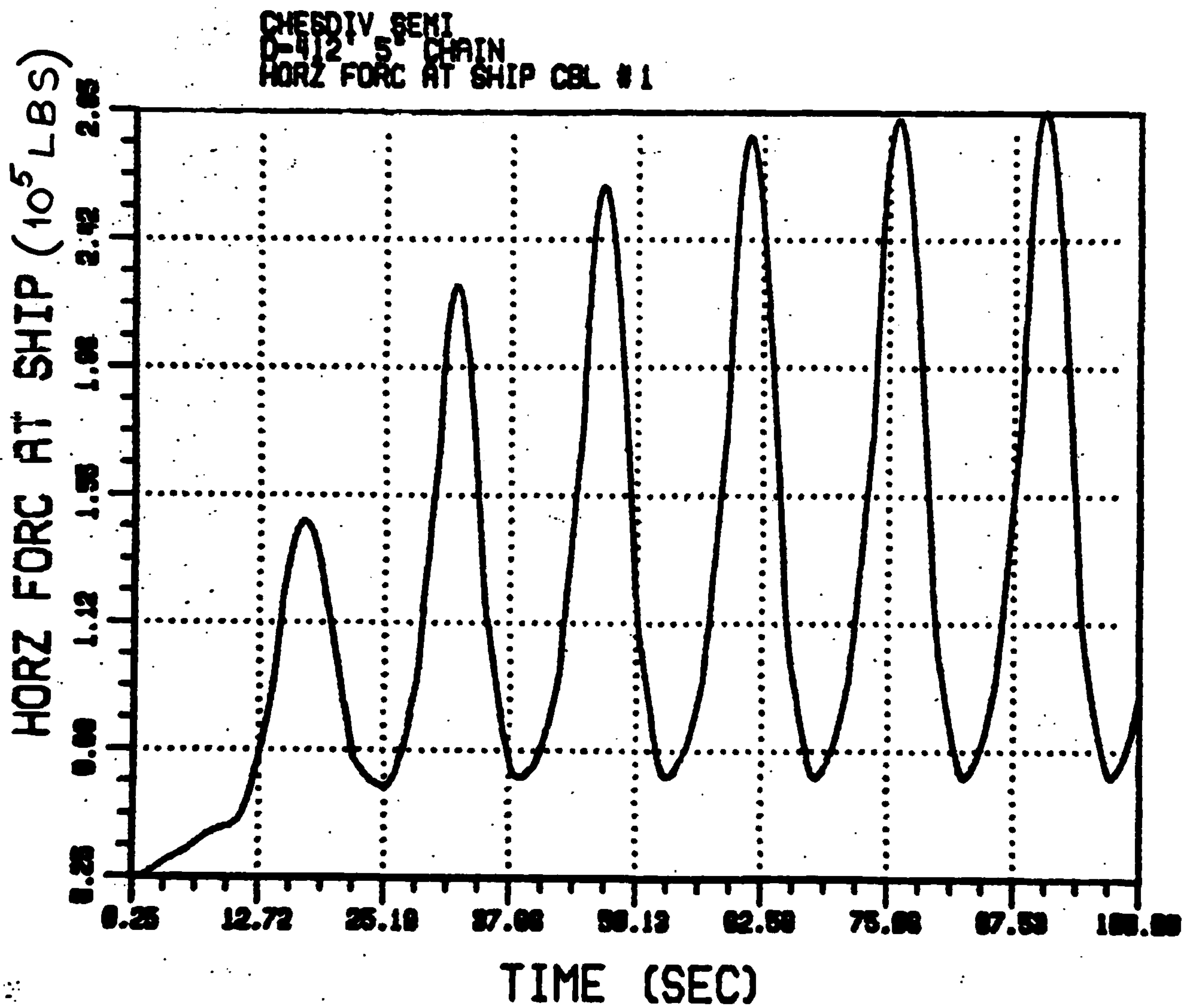


BRIAN WATT ASSOCIATES, INC.

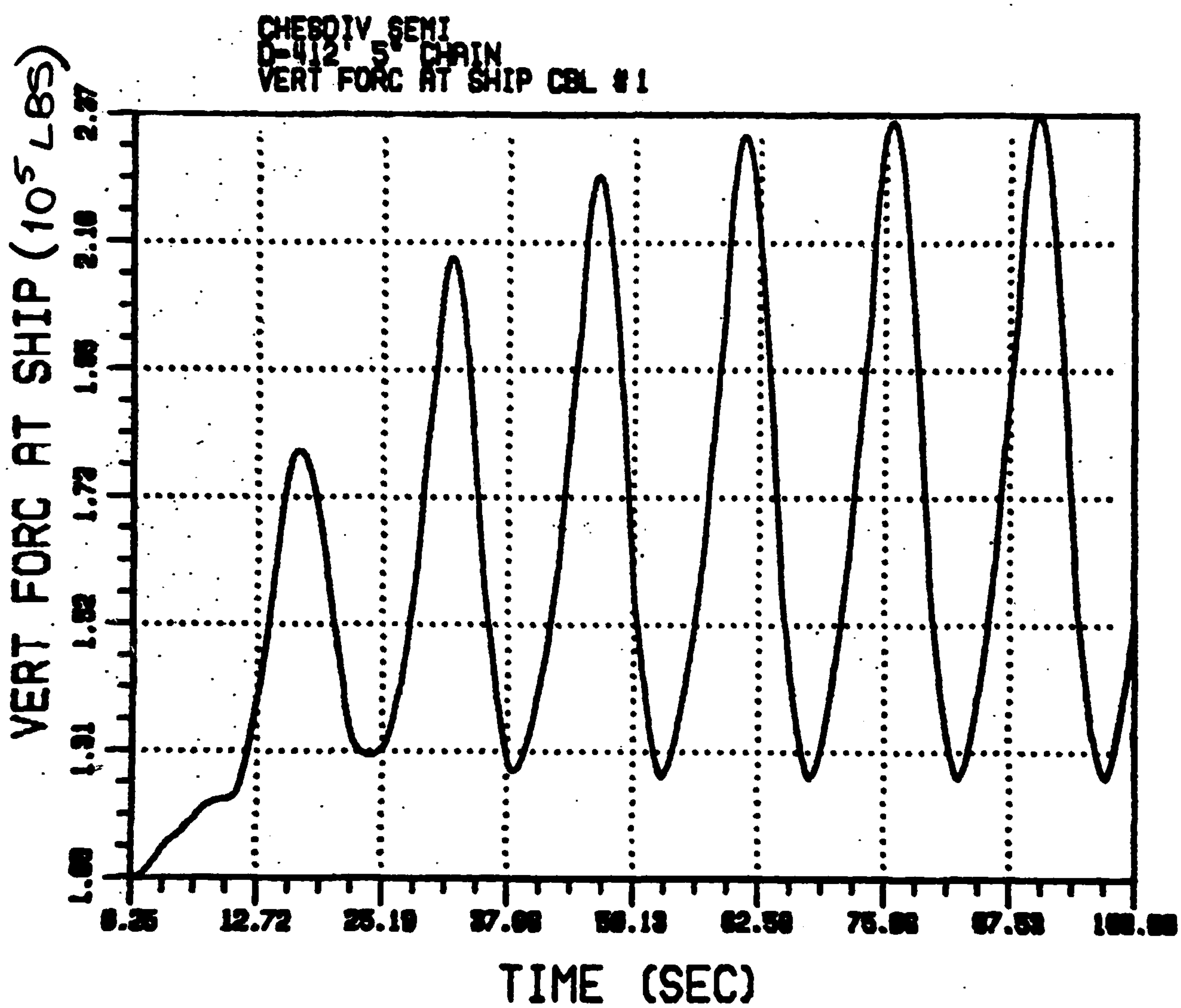

CHESDIV SEMI
D-412' 5" CHAIN
PITCH ANGLE VS. TIME
PITCH ANGLE (DEGREES)
-1.78
-7.47
TIME (SECONDS)
12.50
37.50
BRIAN WATT ASSOCIATES, INC.

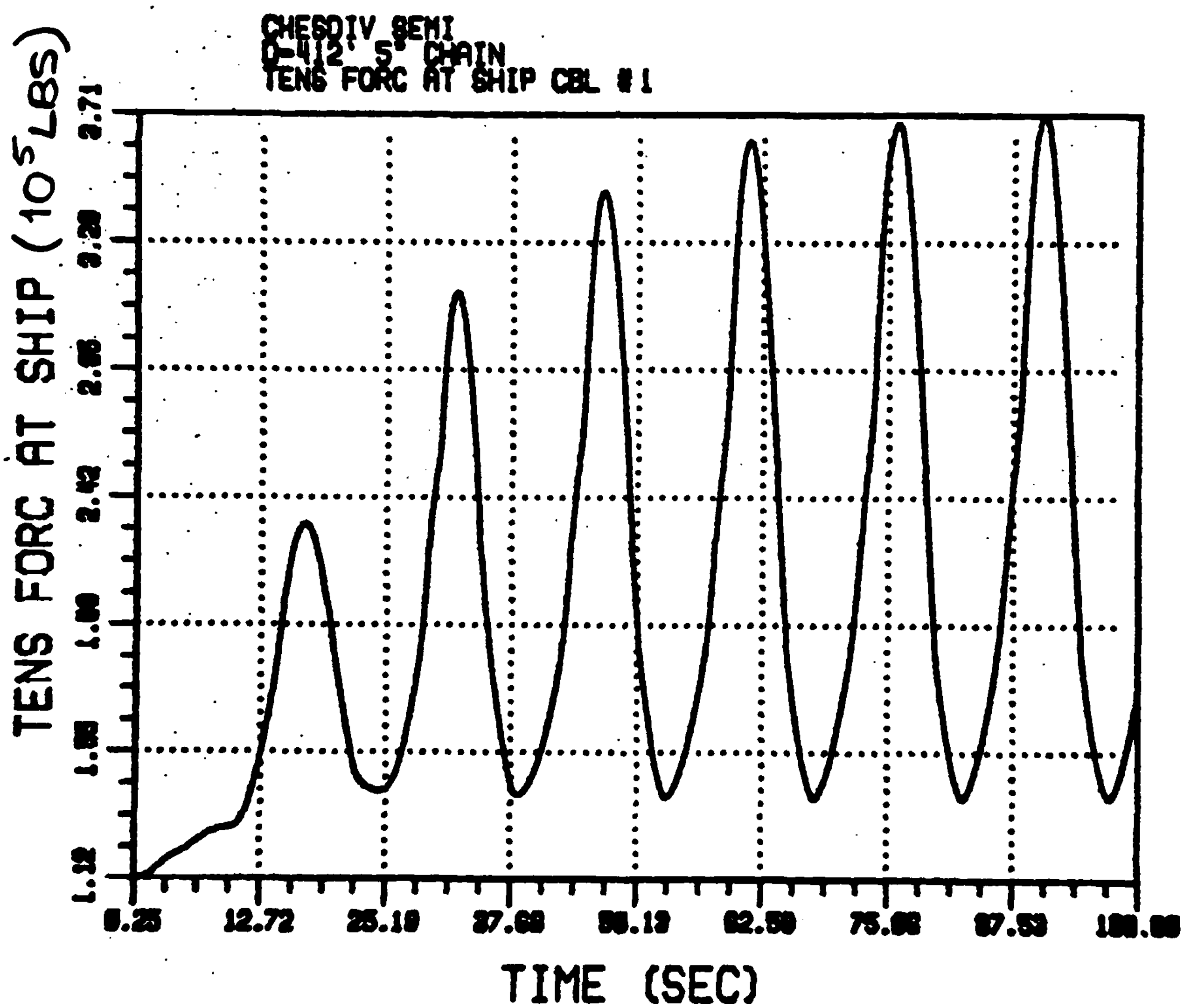
CHESDIV SEMI
D=412' 5" CHAIN
YAW ANGLE VS. TIME

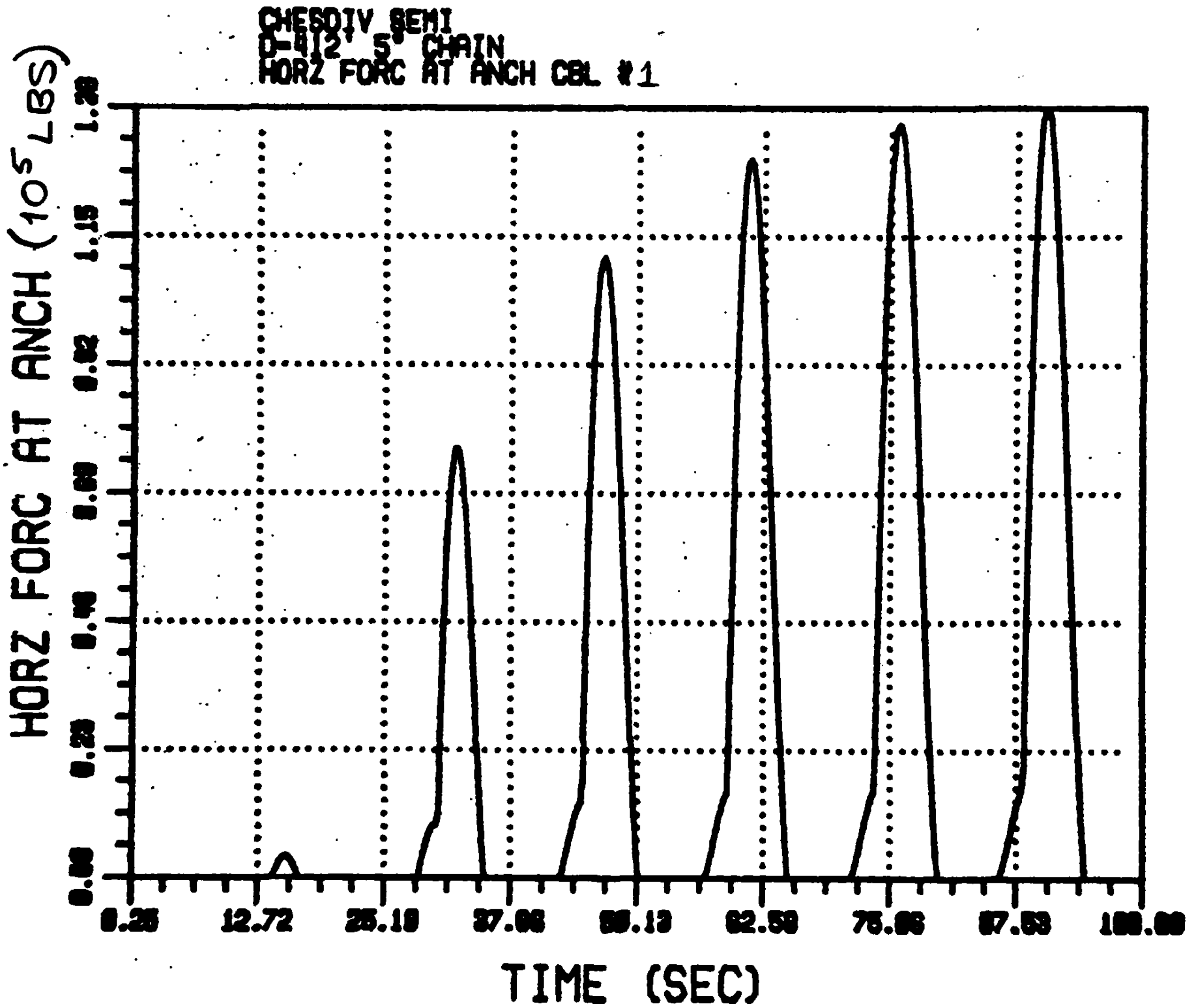




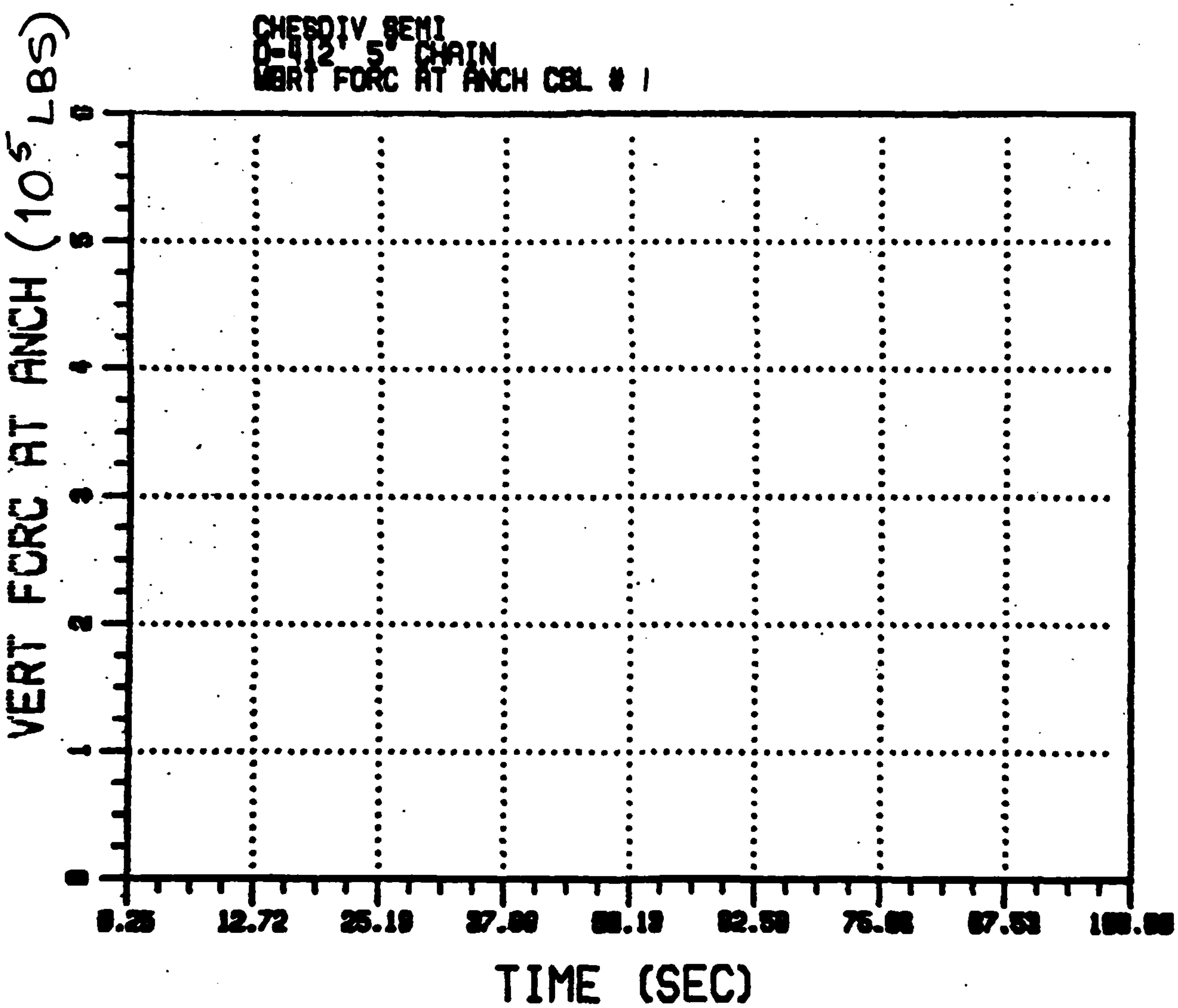
CHESDIV SEMI
HORZ FORC AT SHIP CBL #1
HORZ FORC AT SHIP (10^5 LBS)
1.12
12.72
TIME (SEC)


CHESDIV SEMI
D=412' 5" CHAIN
VERT FORC AT SHIP CBL #1
VERT FORC AT SHIP (10^5 LBS)
TIME (SEC)

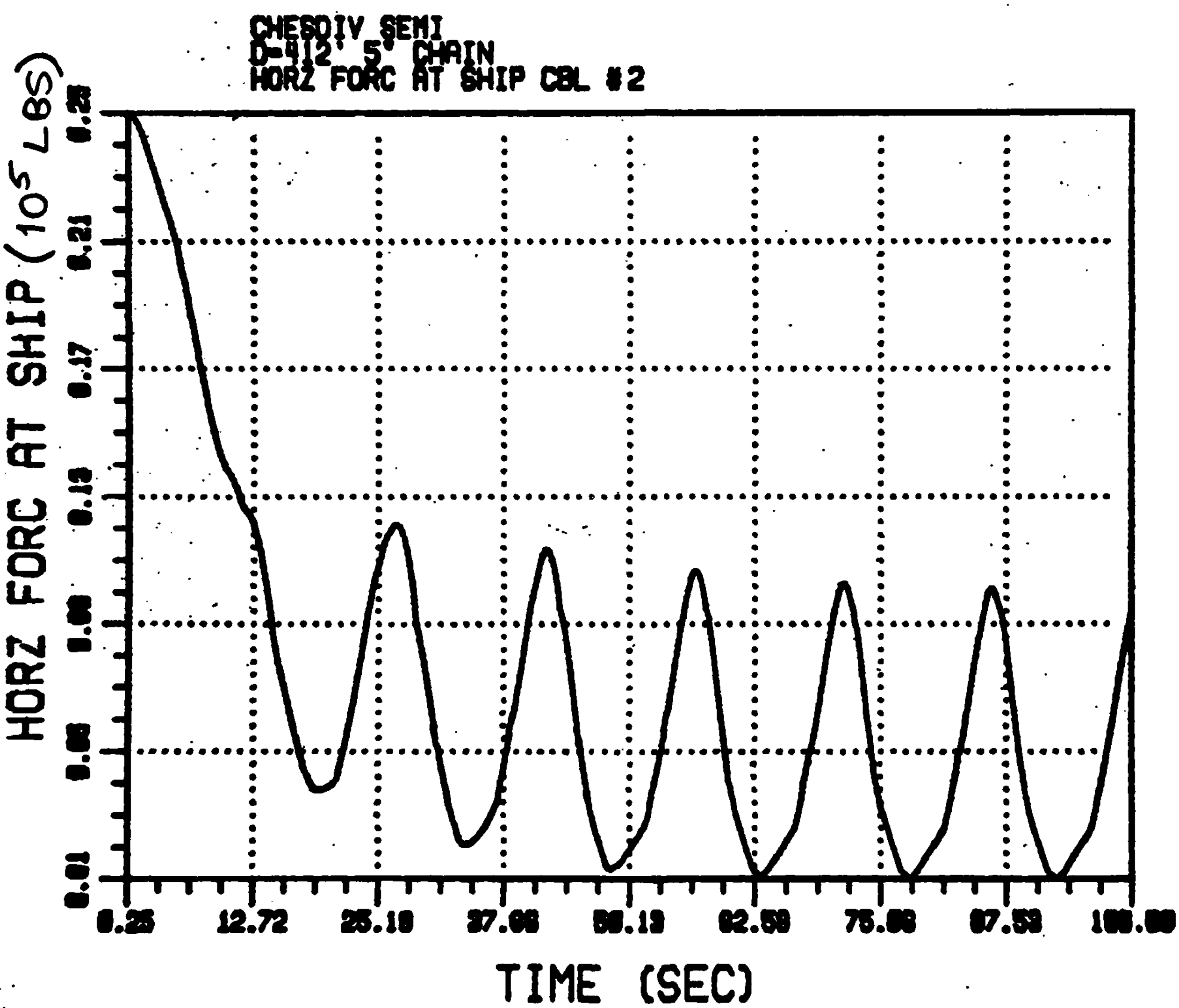

CHESDIV SEMI
TENS FORC AT SHIP CBL #1
TENS FORC AT SHIP $(10^5 LBS)$
2.71
12.72
25.19
TIME (SEC)

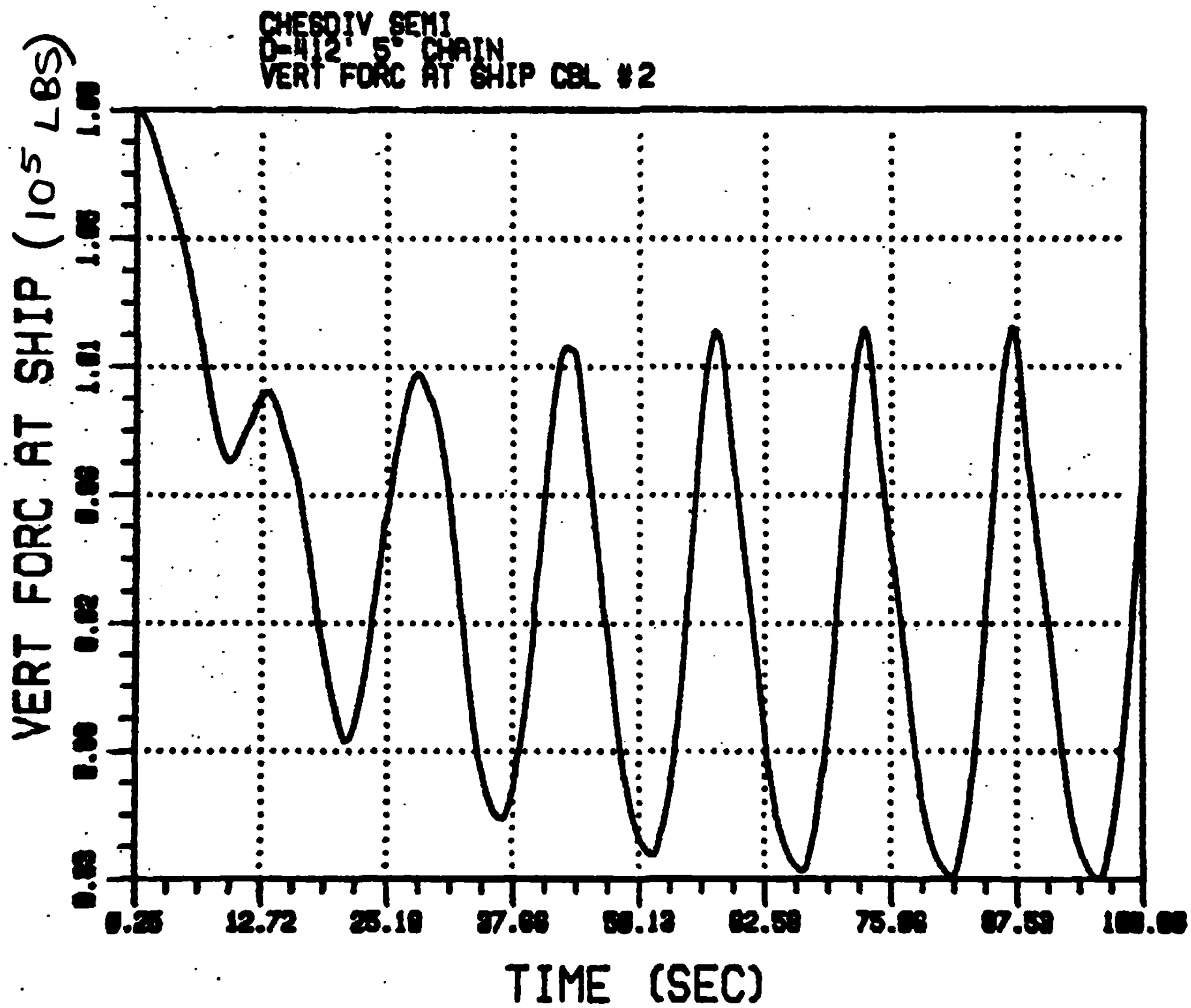


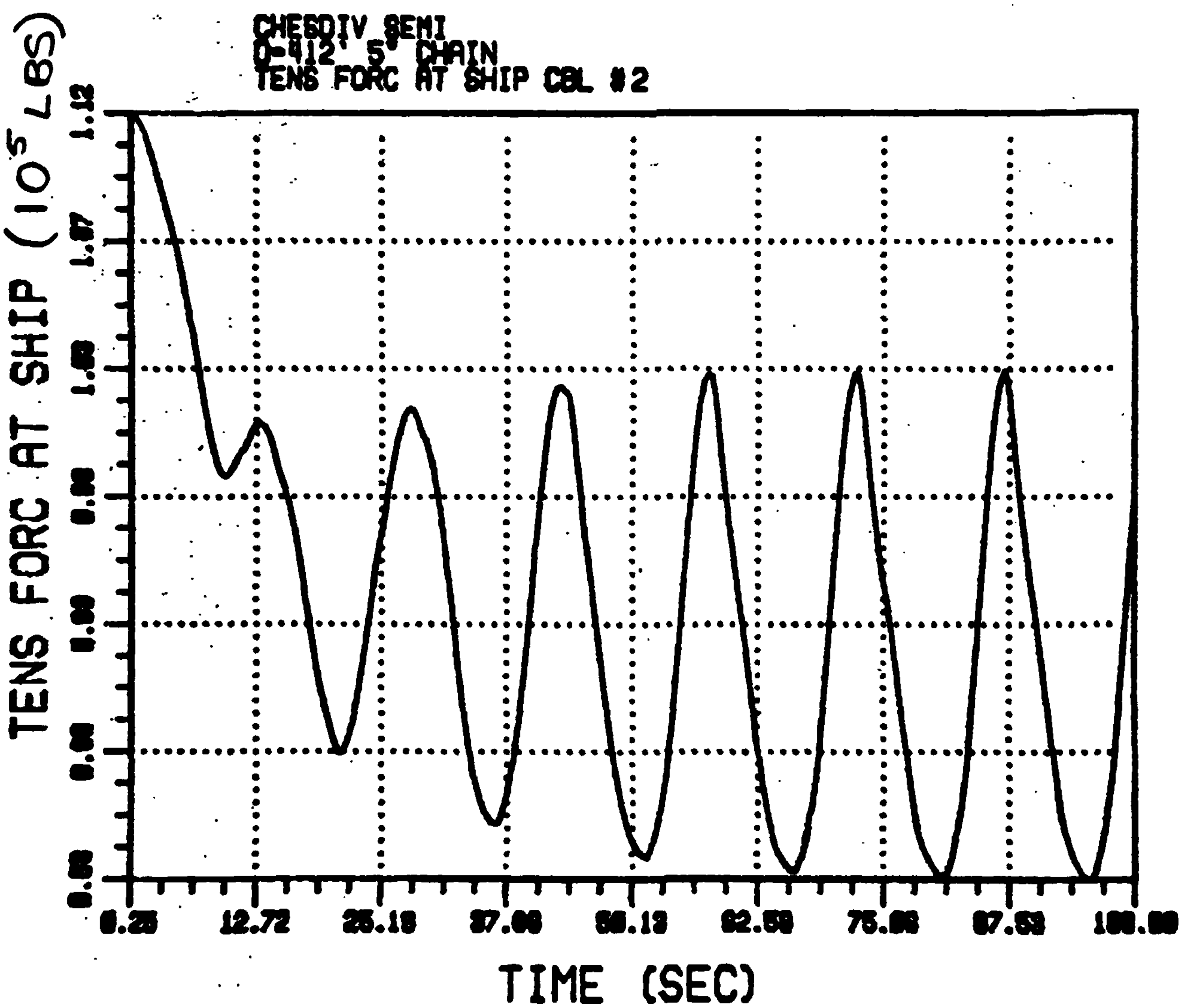
CHESDIV SEMI
D=412' 5" CHAIN
HORZ FORC AT ANCH CBL #1
HORZ FORC AT ANCH $(10^5$ LBS)
TIME (SEC)

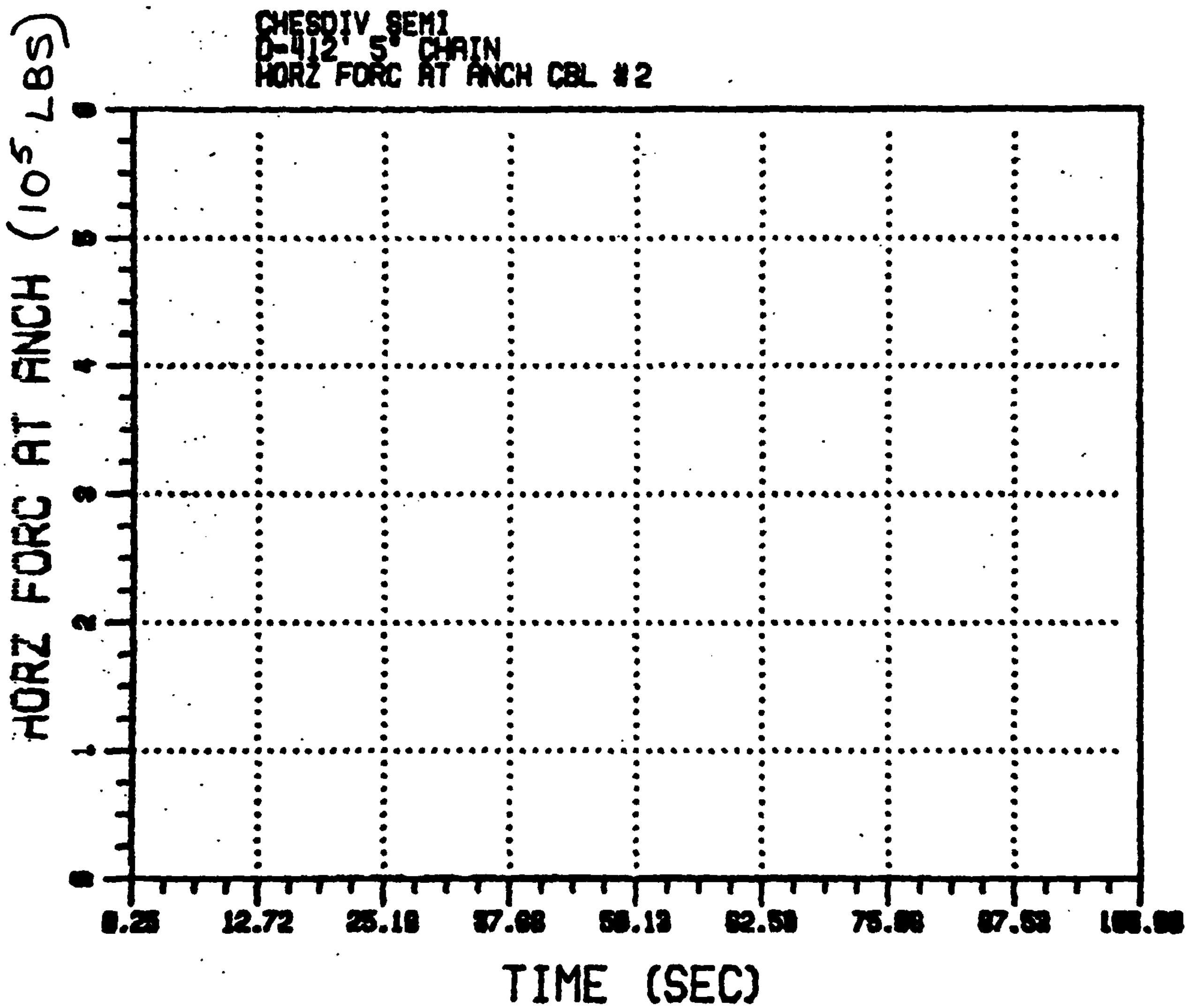


CHESDIV SEMI
0-412' 5" CHAIN
VERT FORC AT ANCH CBL # 1
VERT FORC AT ANCH (10^5 LBS)
TIME (SEC)
12.72
25.19


CHESDIV SEMI
D=412' 5" CHAIN
HORZ FORC AT SHIP CBL #2
HORZ FORC AT SHIP (10^5 LBS)
TIME (SEC)
12.72
25.19


CHESDIV SEMI
D-412' 5" CHAIN
VERT FORC AT SHIP CBL #2
VERT FORC AT SHIP (10^5 LBS)
12.72
TIME (SEC)


CHESDIV SEMI
D=412' 5" CHAIN
TENS FORC AT SHIP CBL #2
TENS FORC AT SHIP (10^5 LBS)
TIME (SEC)
12.72
25.18


CHESDIV SEMI
D-412' 5" CHAIN
HORZ FORC AT ANCH CBL #2
HORZ FORC AT ANCH (10^5 LBS)
1
2
4
12.72
TIME (SEC)

SUMMARY OF RESULTS

EFFECTIVE WATER DEPTH = 412 FT

DESIGN WAVE HEIGHT (FT) = 84.0
WAVE PERIOD (SEC) = 14.6
MAX CREST ELEVATION (FT) = +47.41
MIN TROUGH ELEVATION (FT) = −36.34
MEAN ELEVATION (FT) = +5.54

MAX/MIN SURGE OFFSET (FT) = −147.8/−71.4
MEAN SURGE OFFSET (FT) = −109.6
MAX 1st ORDER MOTIONS (FT) = ± 38.2

MAX/MIN HEAVE OFFSET (FT) = −33.5/24.5
MEAN HEAVE OFFSET (FT) = −4.5
MAX 1st ORDER MOTION (FT) = ± 29.5

MAX/MIN PITCH ANGLE (DEG) = 12.5/8.6
MEAN PITCH ANGLE (DEG) = 2.0
MAX 1st ORDER MOTION (DEG) = ± 10.5

MAX HORIZONTAL FORCE @ VESSEL (KIPS) = 285
MIN HORIZONTAL FORCE @ VESSEL (KIPS) = 58
MEAN HORIZONTAL FORCE @ VESSEL (KIPS) = 171.5

MAX VERTICAL FORCE @ VESSEL (KIPS) = 237
MIN VERTICAL FORCE @ VESSEL (KIPS) = 126
MEAN VERTICAL FORCE @ VESSEL (KIPS) = 181.5

MAX TENSION @ VESSEL (KIPS) = 371
MIN TENSION @ VESSEL (KIPS) = 139
MEAN TENSION @ VESSEL (KIPS) = 255

MAX HORZ. FORCE @ ANCHOR (KIPS) = 138
MIN HORZ. FORCE @ ANCHOR (KIPS) = 0

MAX VERTICAL FORCE @ ANCHOR (KIPS) = —
MIN VERTICAL FORCE @ ANCHOR (KIPS) = —

CHAIN DIAMETER (IN) = 5.0
LENGTH OF CHAIN (FT) = 2,000
LOCATION OF ANCHOR (FT) = 1,750
PROOF LOAD (KIPS) = 1,203

(PEAK TENSION / PROOF LOAD) × 100 = 30.84 %

APPENDIX A.2

WATER DEPTH	=	250 FT
EFFECTIVE WATER DEPTH	=	262 FT
WAVE HEIGHT	=	72 FT
WAVE PERIOD	=	14.0 SEC
CURRENT	=	3 KN
WIND	=	150 KN
MOORING CHAIN	=	5 IN

ITEM	WEIGHT (S. TONS)
SEMISUBMERSIBLE + PAYLOAD	65.1
MOORING SYSTEM VERTICAL COMPONENT	88.0
BALLAST	99.9
TOTAL DISPLACEMENT	253.0

SEMISUBMERSIBLE WEIGHT DISTRIBUTION

DEPTH = 262 FT

**** CALCULATED DISPLACEMENT PROPERTIES ****

DISPLACEMENT	=	0.49987E 06
CENTER OF BUOYANCY ALONG X-AXIS	=	0.00
CENTER OF BUOYANCY ALONG Y-AXIS	=	0.00
CENTER OF BUOYANCY ALONG Z-AXIS	=	-19.89

**** STRUCTURAL INPUT PROPERTIES ****

STRUCTURAL WEIGHT	=	0.33000E 06
ROLL RADIUS OF GYRATION	=	25.20
PITCH RADIUS OF GRYRATION	=	25.20
YAW RADIUS OF GRYRATION	=	31.10
CENTER OF GRAVITY ALONG X-AXIS	=	0.00
CENTER OF GRAVITY ALONG Y-AXIS	=	0.00
CENTER OF GRAVITY ALONG Z-AXIS	=	-17.90

**** WATER INPUT PROPERTIES ****

MASS DENSITY OF WATER	=	1.99
ACCELERATION OF GRAVITY	=	32.17
WAVE HEIGHT	=	72.00
WAVE PERIOD	=	14.00
WATER DEPTH	=	262.00
ANGLE OF ATTACK IN DEGREES	=	180.00

**** CALCULATED WATERPLANE PROPERTIES ****

WATERPLANE AREA	=	94.51
CENTER OF AREA ALONG X-AXIS	=	0.00
CENTER OF AREA ALONG Y-AXIS	=	-0.00
WATERPLANE INERTIA ABOUT X-AXIS	=	0.66787E 05
WATERPLANE INERTIA ABOUT Y-AXIS	=	0.66783E 05
METACENTRIC HEIGHT IN ROLL	=	6.57
METACENTRIC HEIGHT IN PITCH	=	6.57

**** CENTERS ARE IN ORIGINAL SYSTEM ****

**** INERTIAS ARE ABOUT AXES THRU CG ***

FREQUENCY DOMAIN RESULTS

UNITS: LBS, FEET

**** CALCULATED DISPLACEMENT PROPERTIES ****

DISPLACEMENT	=	0.49987E 06
CENTER OF BUOYANCY ALONG X-AXIS	=	0.00
CENTER OF BUOYANCY ALONG Y-AXIS	=	0.00
CENTER OF BUOYANCY ALONG Z-AXIS	=	-19.89

**** STRUCTURAL INPUT PROPERTIES ****

STRUCTURAL WEIGHT	=	0.33000E 06
ROLL RADIUS OF GYRATION	=	25.20
PITCH RADIUS OF GRYRATION	=	25.20
YAW RADIUS OF GRYRATION	=	31.10
CENTER OF GRAVITY ALONG X-AXIS	=	0.00
CENTER OF GRAVITY ALONG Y-AXIS	=	0.00
CENTER OF GRAVITY ALONG Z-AXIS	=	-17.90

**** WATER INPUT PROPERTIES ****

MASS DENSITY OF WATER	=	1.99
ACCELERATION OF GRAVITY	=	32.17
WAVE HEIGHT	=	72.00
WAVE PERIOD	=	14.00
WATER DEPTH	=	262.00
ANGLE OF ATTACK IN DEGREES	=	180.00

**** CALCULATED WATERPLANE PROPERTIES ****

WATERPLANE AREA	=	94.51
CENTER OF AREA ALONG X-AXIS	=	0.00
CENTER OF AREA ALONG Y-AXIS	=	-0.00
WATERPLANE INERTIA ABOUT X-AXIS	=	0.66787E 05
WATERPLANE INERTIA ABOUT Y-AXIS	=	0.66783E 05
METACENTRIC HEIGHT IN ROLL	=	6.57
METACENTRIC HEIGHT IN PITCH	=	6.57

**** CENTERS ARE IN ORIGINAL SYSTEM ****

**** INERTIAS ARE ABOUT AXES THRU CG ***

FREQUENCY DOMAIN RESULTS

UNITS: LBS, FEET

BODY MASS MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.10256729E 05	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00
SWAY	0.00000000E 00	0.10256729E 05	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00
HEAVE	0.00000000E 00	0.00000000E 00	0.10256729E 05	0.00000000E 00	0.00000000E 00	0.00000000E 00
ROLL	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.65134332E 07	0.00000000E 00	0.00000000E 00
PITCH	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.65134332E 07	0.00000000E 00
YAW	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.99204109E 07

ADDED MASS MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.96193757E 04	-0.20929747E-09	-0.64801498E-11	-0.12514647E-08	-0.84683652E 03	0.24875956E-01
SWAY	-0.20929747E-09	0.96179669E 04	-0.34106051E-11	0.83816110E 03	-0.12496457E-08	0.22230983E 02
HEAVE	-0.64801498E-11	-0.34106051E-11	0.12226625E 05	0.24875950E-01	-0.31666512E 02	-0.13096724E-09
ROLL	-0.12514647E-08	0.83816110E 03	0.24875950E-01	0.47648952E 07	-0.69180543E 00	-0.56552540E 02
PITCH	-0.84683652E 03	-0.12496457E-08	-0.31666512E 02	-0.69180545E 00	0.47642081E 07	-0.15381561E 00
YAW	0.24875956E-01	0.22230983E 02	-0.13096724E-09	-0.56552540E 02	-0.15381562E 00	0.95184866E 07

HYDROSTATIC STIFFNESS MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00
SWAY	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00
HEAVE	0.00000000E 00	0.00000000E 00	0.60525515E 04	-0.46596940E-09	-0.20175172E 02	0.00000000E 00
ROLL	0.00000000E 00	0.00000000E 00	-0.46596940E-09	0.32822065E 07	-0.15532313E-11	0.00000000E 00
PITCH	0.00000000E 00	0.00000000E 00	-0.20175172E 02	-0.15532313E-11	0.32819565E 07	0.00000000E 00
YAW	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00

MOORING STIFFNESS MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.42656121E 03	-0.22737368E-12	0.10864439E 03	-0.18917490E-09	0.12507398E 05	0.14551915E-10
SWAY	-0.22737368E-12	0.92147124E 02	-0.22737368E-12	-0.55023210E 04	-0.14551915E-10	0.33997682E 04
HEAVE	0.10864439E 03	-0.22737368E-12	0.10585500E 04	-0.29103830E-10	0.31122651E 03	0.36379788E-10
ROLL	-0.18917490E-09	-0.55023210E 04	-0.29103830E-10	0.90763868E 06	-0.46566129E-08	-0.22274273E 06
PITCH	0.12507398E 05	-0.14551915E-10	0.31122651E 03	-0.46566129E-08	0.94547928E 06	0.23283064E-09
YAW	0.14551915E-10	0.33997682E 04	0.36379788E-10	-0.22274273E 06	0.23283064E-09	0.15163502E 06

MODE SHAPE MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.99986490E 00	-0.84350653E-09	0.16828355E-01	-0.73231204E-05	0.86315291E 00	0.69768175E-07
SWAY	-0.24732278E-07	0.99971271E 00	-0.12038949E-07	-0.62921107E 00	-0.19554250E-05	0.99908470E 00
HEAVE	-0.16138121E-01	0.12859004E-10	0.99985809E 00	-0.72644266E-05	0.17408936E 00	-0.94818087E-09
ROLL	-0.16014692E-09	0.38803565E-04	0.12635227E-07	0.77684178E 00	0.24436050E-05	0.36881190E-02
PITCH	-0.31226492E-02	0.29529777E-11	-0.78218132E-03	-0.39414825E-05	0.47398306E 00	-0.23689841E-09
YAW	-0.23955308E-08	-0.23968589E-01	-0.50442658E-09	-0.24703782E-01	-0.74069658E-07	0.42616396E-01

NATURAL PERIOD IN SURGE= 0.45104886E 02
NATURAL PERIOD IN SWAY = 0.27437145E 03
NATURAL PERIOD IN HEAVE= 0.11171033E 02
NATURAL PERIOD IN ROLL = 0.10294208E 02
NATURAL PERIOD IN PITCH= 0.10234068E 02
NATURAL PERIOD IN YAW = 0.60157619E 02

PERIOD	LENGTH	SURGE	PHASE	SWAY	PHASE	HEAVE	PHASE	ROLL	PHASE	PITCH	PHASE	YAW	PHASE
14.00	944.08	0.9668	43.02	0.0000	-34.97	0.8364	-163.25	0.00000	103.71	0.13394	-78.28	0.00000	-39.21

WAVE PERIOD= 14.00

	INERTIAL FORCES		FROUDE-KRYLOV FORCES		VICOUS DRAG FORCES	
	AMPLITUDE	PHASE SHIFT	AMPLITUDE	PHASE SHIFT	AMPLITUDE	PHASE SHIFT
SURGE	0.65386880E 05	0.91609001E 02	0.10264269E 06	0.90096270E 02	0.33424287E 06	-0.17892448E 03
SWAY	0.82343324E-03	-0.87523173E 01	0.91491890E-03	-0.87526012E 01	0.45094041E-02	0.90313927E 02
HEAVE	0.74476960E 05	-0.17999912E 03	0.13624738E 06	0.49281786E-01	0.49322482E 06	-0.89155605E 02
ROLL	0.14676634E 00	0.16933350E 03	0.16307394E 00	0.16933348E 03	0.50737212E 00	-0.10321560E 03
PITCH	0.14958717E 06	-0.87224199E 02	0.57884416E 06	0.84926449E 02	0.72762380E 06	-0.21596116E 02
YAW	0.16471731E 00	0.77920268E 02	0.18301906E 00	0.77920379E 02	0.86831002E 00	0.16707156E 03

DAMPING MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.22124105E 05	0.46399454E-04	-0.30544266E 03	0.54985021E-03	0.21754951E 05	0.58782682E-01
SWAY	0.46399454E-04	0.19980306E 05	-0.10785721E-04	-0.29281825E 05	-0.22646361E-03	0.23494204E 05
HEAVE	-0.30544266E 03	-0.10785721E-04	0.36028746E 05	0.39060927E-01	0.25507146E 05	-0.32339353E-03
ROLL	0.54985021E-03	-0.29281825E 05	0.39060927E-01	0.13842372E 08	-0.12414624E 01	0.93049142E 05
PITCH	0.21754951E 05	-0.22646361E-03	0.25507146E 05	-0.12414624E 01	0.14208982E 08	-0.36982804E 00
YAW	0.58782682E-01	0.23494204E 05	-0.32339353E-03	0.93049142E 05	-0.36982804E 00	0.19148023E 08

CATENARY MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.42693815E 03	-0.34106051E-12	0.10870245E 03	-0.58207661E-10	0.12507974E 05	0.00000000E 00
SWAY	-0.34106051E-12	0.91407820E 02	-0.22737368E-12	-0.54925599E 04	-0.72759576E-11	0.34058265E 04
HEAVE	0.10870245E 03	-0.22737368E-12	0.10585500E 04	-0.87311491E-10	0.31124051E 03	-0.14551915E-10
ROLL	-0.58207661E-10	-0.54925599E 04	-0.87311491E-10	0.90758507E 06	-0.27939677E-08	-0.22261689E 06
PITCH	0.12507974E 05	-0.72759576E-11	0.31124051E 03	-0.27939677E-08	0.94545990E 06	0.11641532E-09
YAW	0.00000000E 00	0.34058265E 04	-0.14551915E-10	-0.22261689E 06	0.11641532E-09	0.15135162E 06

MOORING SYSTEM USED: 5" GRADE 2 CHAIN

LENGTH OF CHAIN: 2000 FT

LOCATION OF ANCHOR: 1800 FT

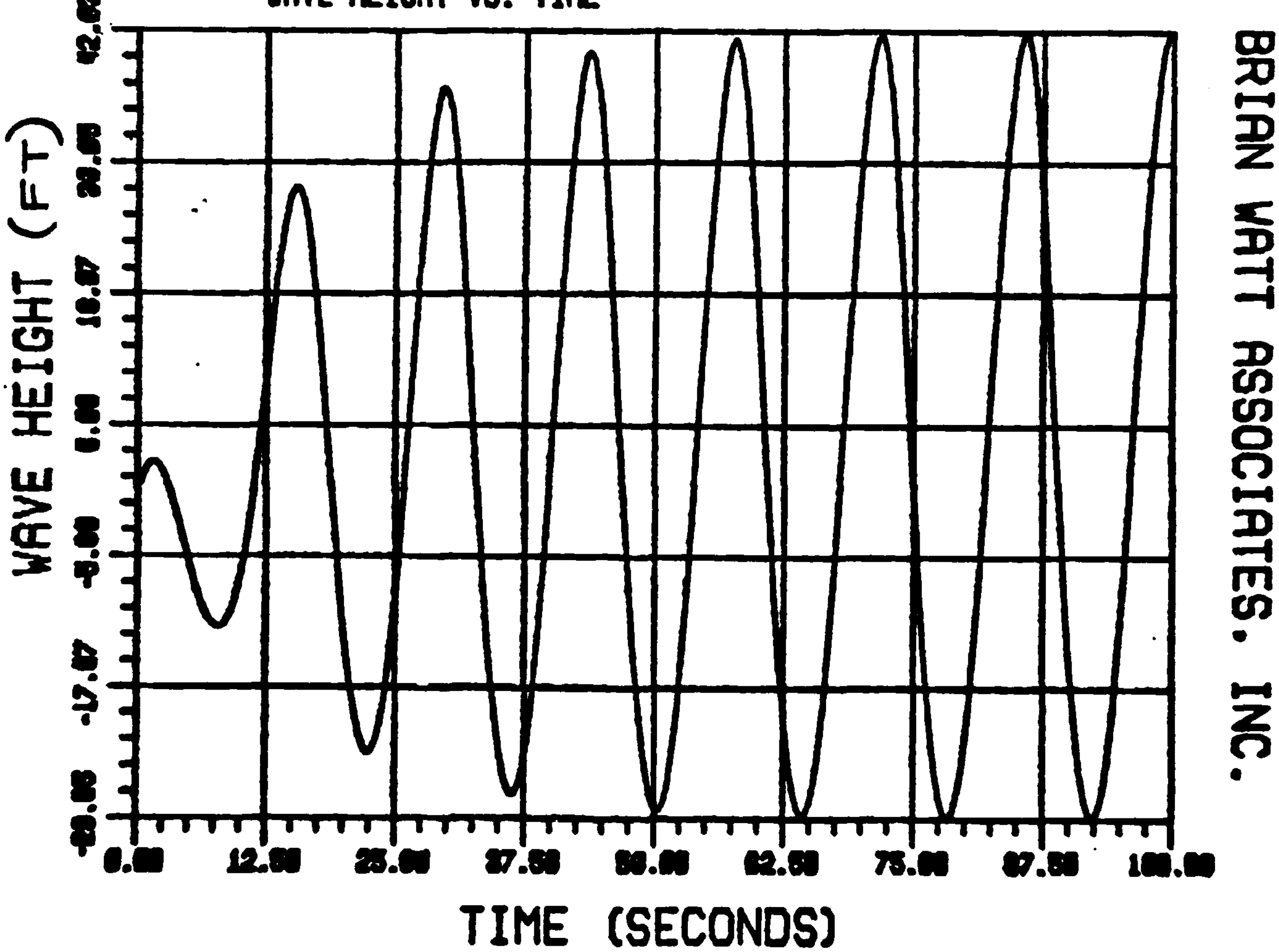
FORCES IN CATENARY LINES

PERIOD	ELEMENT	MIN HOR FOR AT SHP MAX HOR FOR AT SHP	MIN VER FOR AT SHP MAX VER FOR AT SHP	MIN TEN AT SHP MAX TEN AT SHP	MIN HOR FOR AT BOT MAX HOR FOR AT BOT	MIN VER FOR AT BOT MAX VER FOR AT BOT
14.00	1	0.44303098E 05	0.79778250E 05	0.91293286E 05	0.00000000E 00	0.00000000E 00
		0.57257445E 06	0.26851215E 06	0.63240831E 06	0.44063340E 06	0.00000000E 00
14.00	2	0.10000000E-05	0.47692598E 05	0.47692598E 05	0.00000000E 00	0.00000000E 00
		0.15006640E 02	0.60527223E 05	0.60527223E 05	0.00000000E 00	0.00000000E 00
14.00	3	0.10000000E-05	0.47692598E 05	0.47692598E 05	0.00000000E 00	0.00000000E 00
		0.15006627E 02	0.60527223E 05	0.60527223E 05	0.00000000E 00	0.00000000E 00

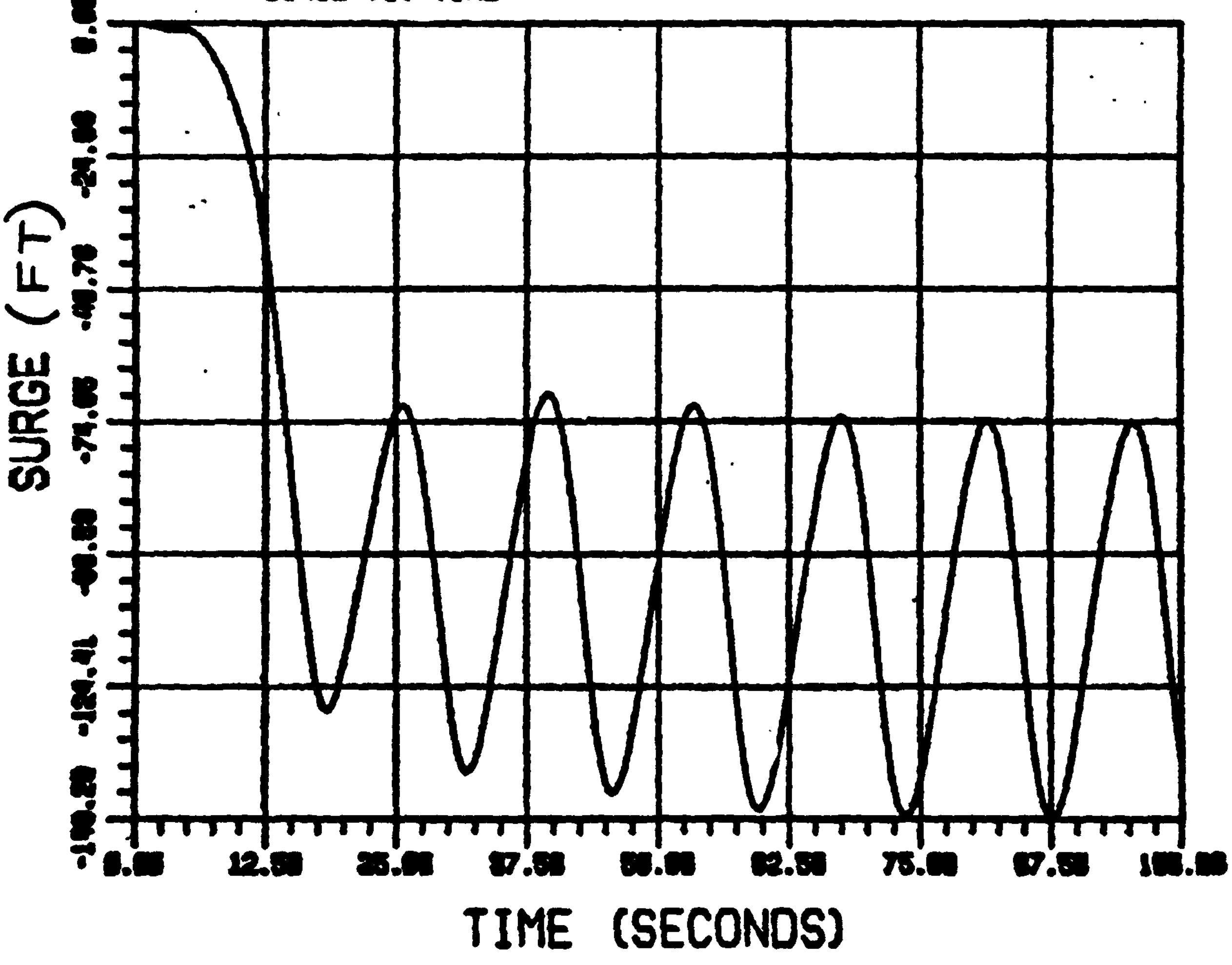
FORCES AT ANCHOR

FORCES IN LBS.

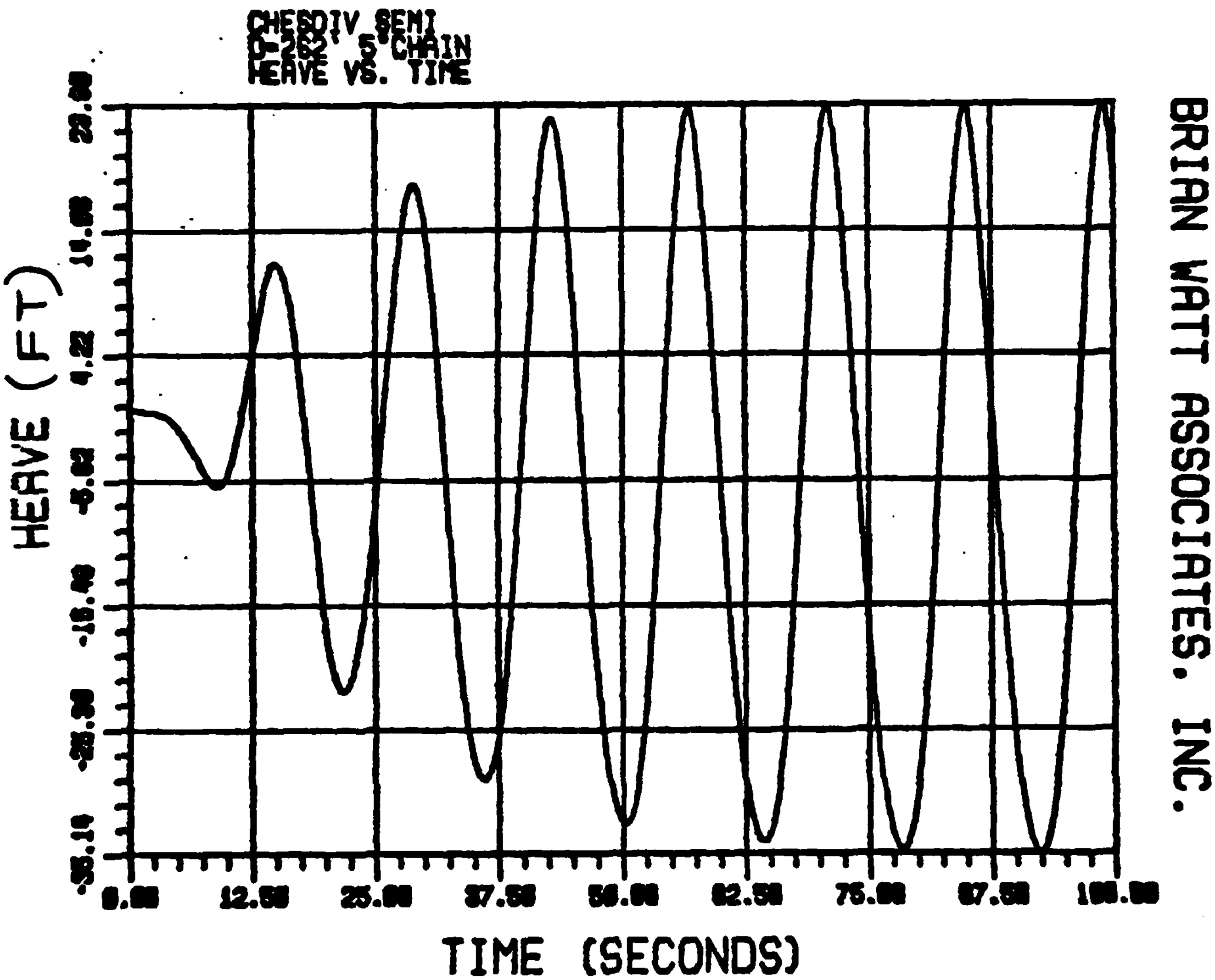
CHESDIV SEMI
D-262' 5"CHAIN
WAVE HEIGHT VS. TIME

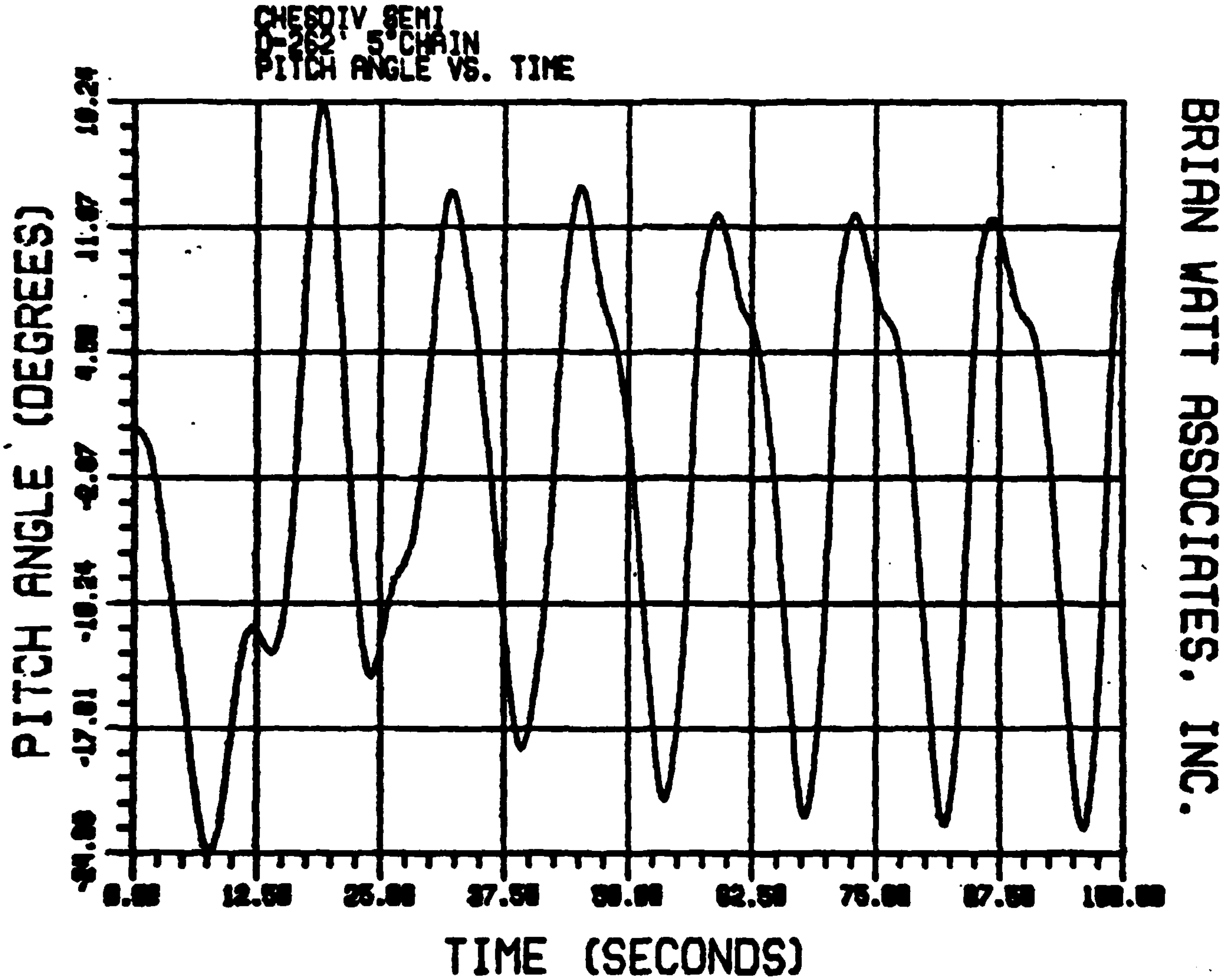


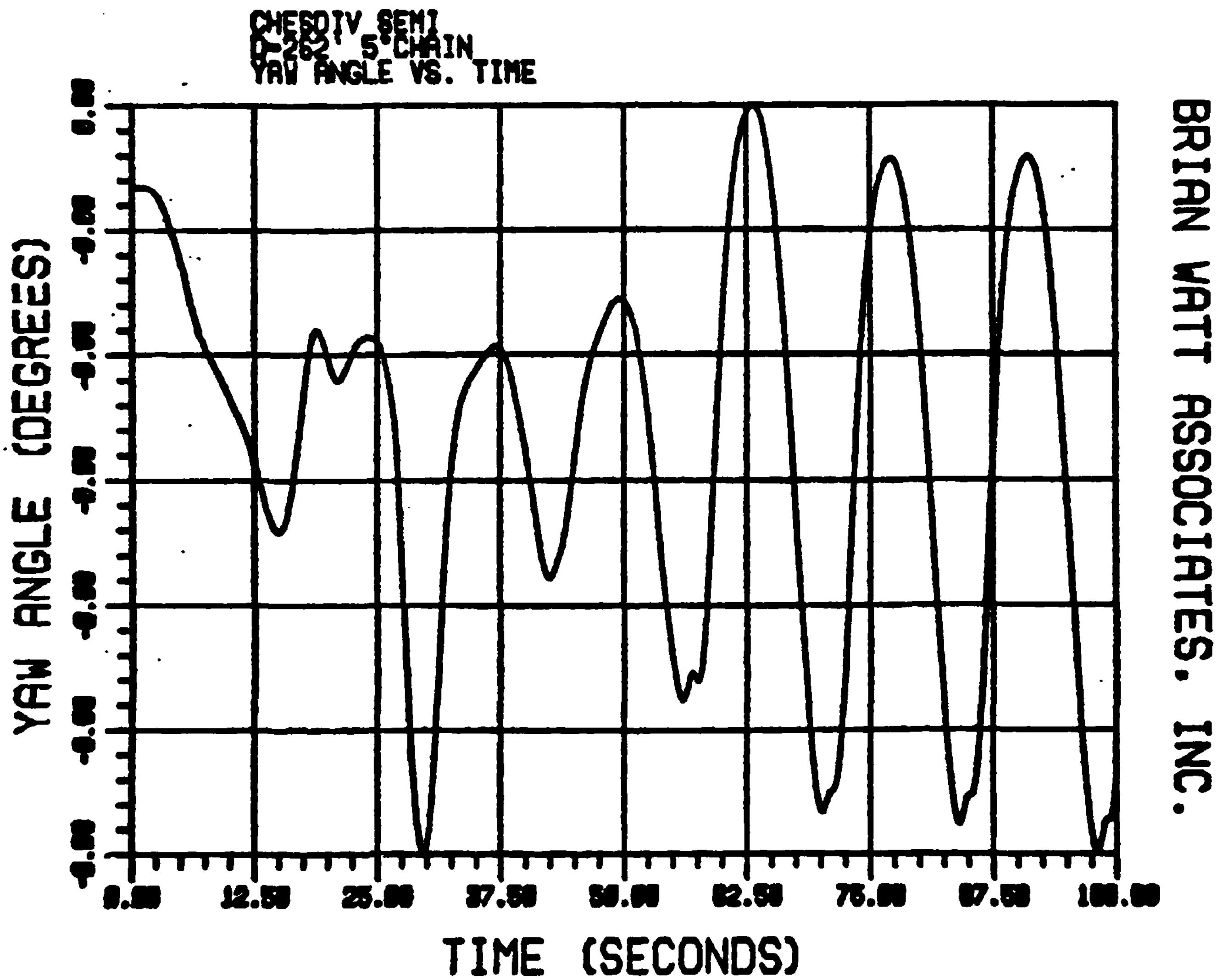
CHESDIV SEMI
D-262' 5"CHAIN
SURGE VS. TIME

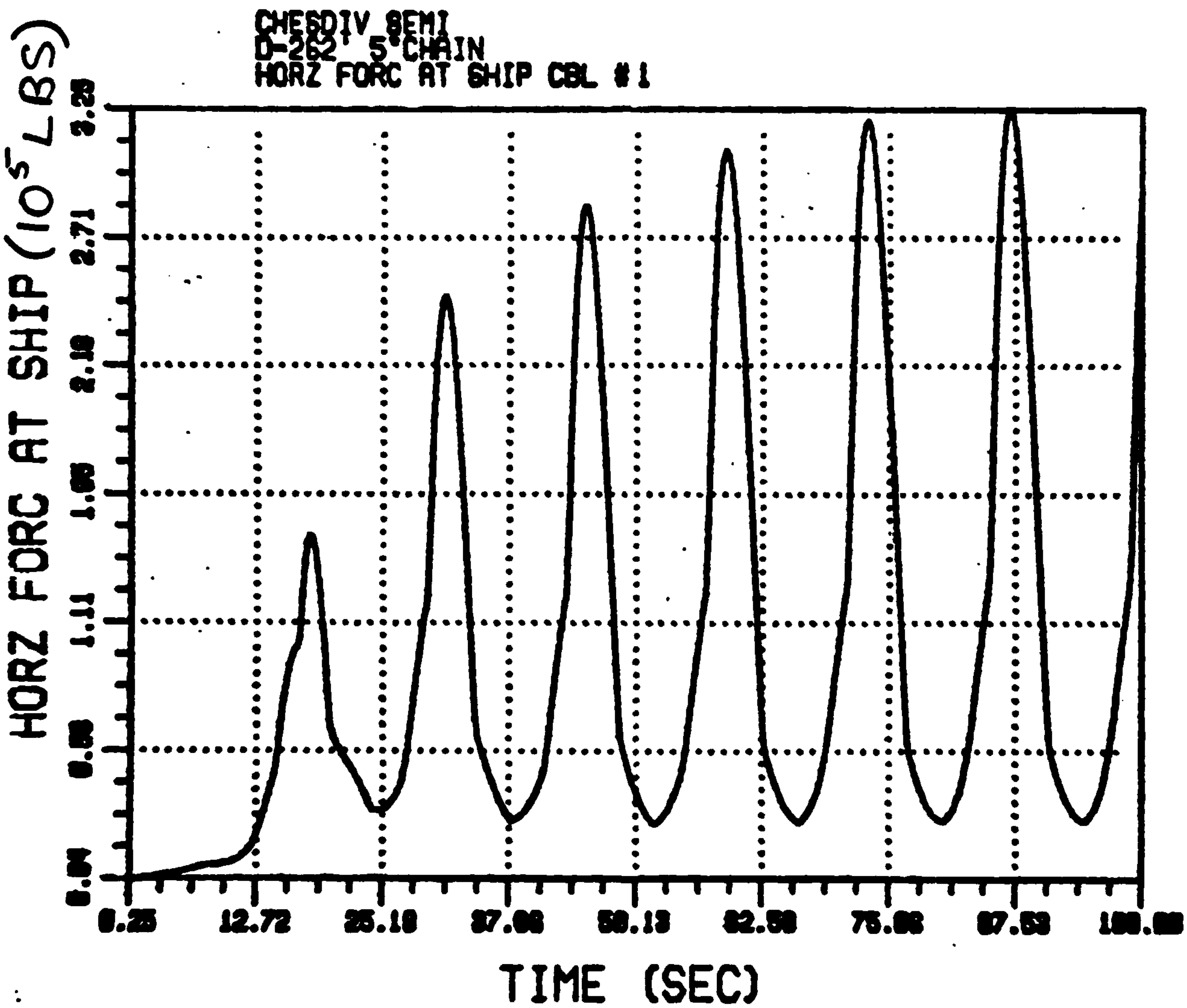


BRIAN WATT ASSOCIATES, INC.

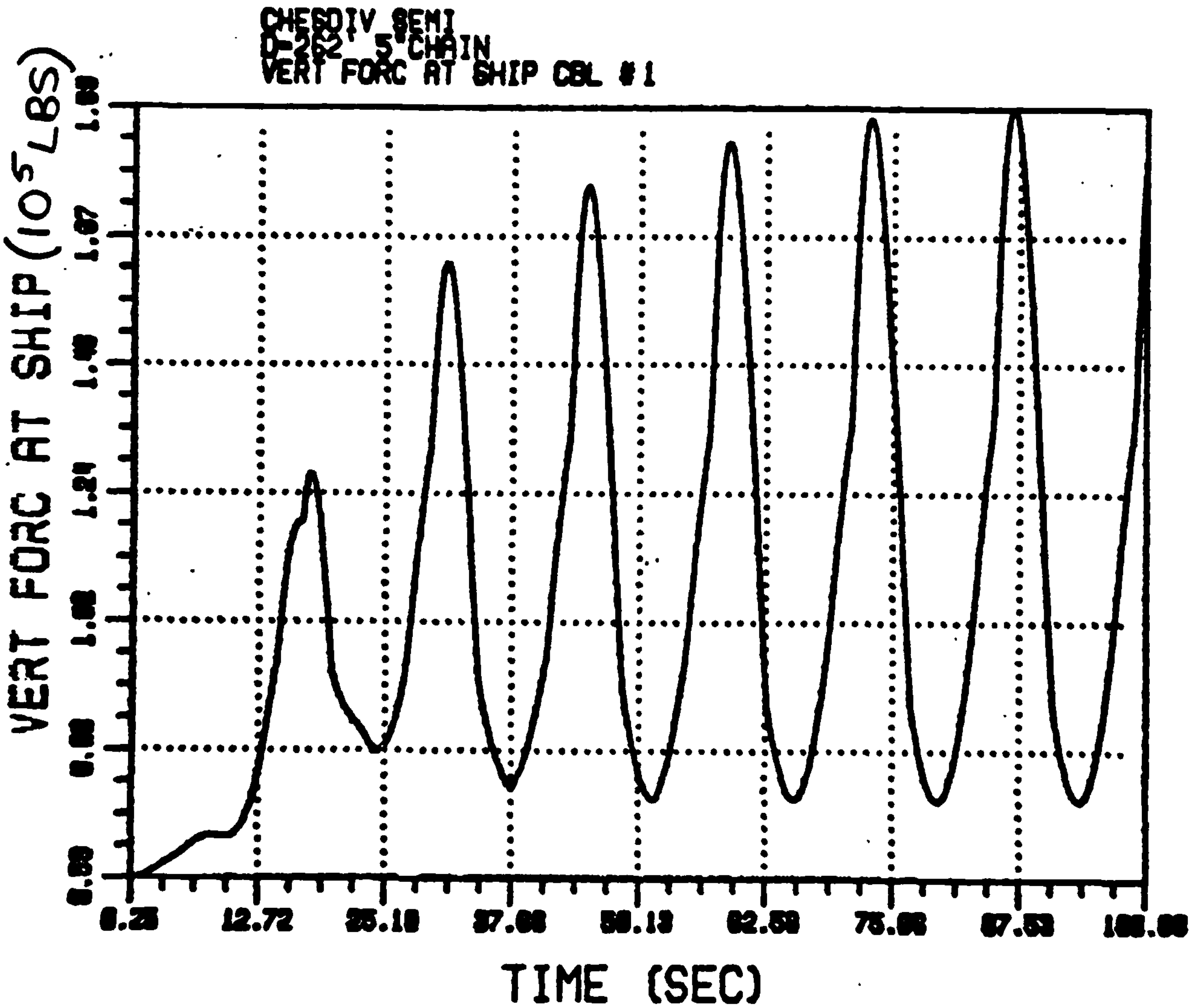

CHESDIV SEMI
D=262' 5"CHAIN
HEAVE VS. TIME
HEAVE (FT)
TIME (SECONDS)
BRIAN WATT ASSOCIATES, INC.

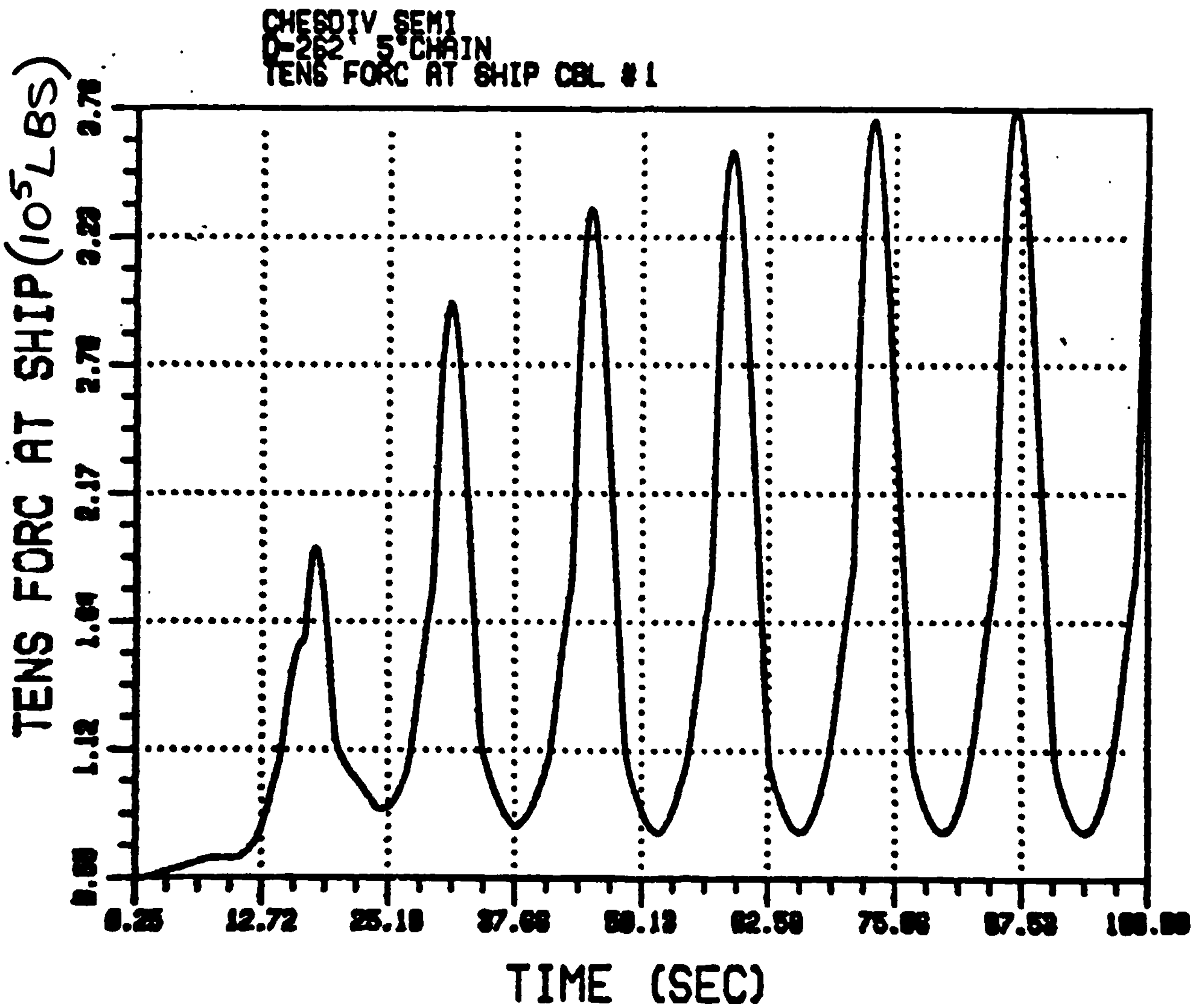

CHESDIV SEMI
D=262' 5"CHAIN
PITCH ANGLE VS. TIME
PITCH ANGLE (DEGREES)
12.50
25.00
37.50
50.00
62.50
75.00
87.50
100.00
TIME (SECONDS)
BRIAN WATT ASSOCIATES, INC.

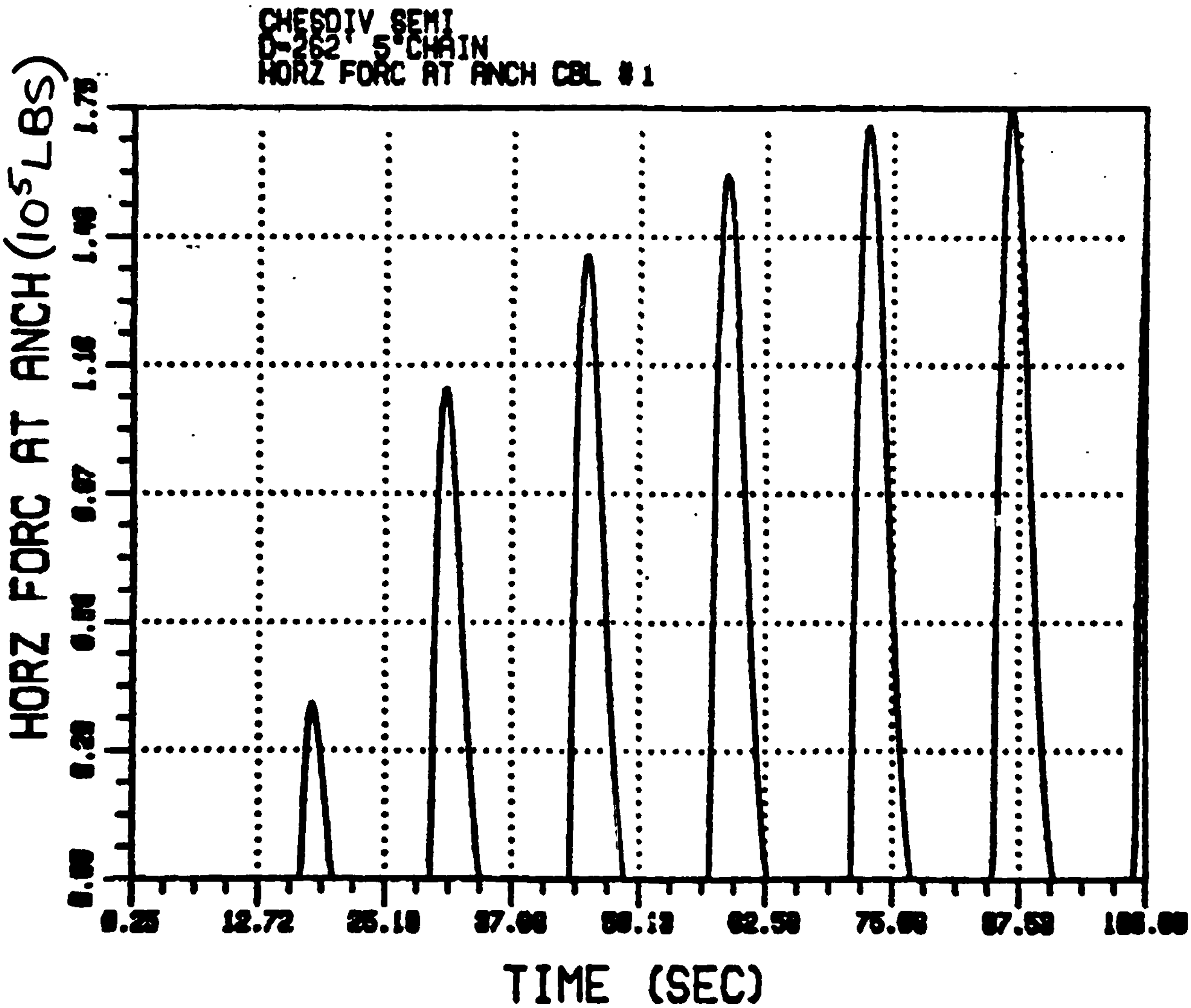

CHESDIV SEMI
5'CHAIN
YAW ANGLE VS. TIME
YAW ANGLE (DEGREES)
12.50
TIME (SECONDS)
BRIAN WATT ASSOCIATES, INC.



CHESDIV SEMI
D-262' 5"CHAIN
HORZ FORC AT SHIP CBL #1
HORZ FORC AT SHIP (10^5 LBS)
2.71
1.11
0.25
12.72
25.19
TIME (SEC)


CHESDIV SEMI
D-262' 5"CHAIN
VERT FORC AT SHIP CBL #1
VERT FORC AT SHIP (10^5LBS)
TIME (SEC)
12.72
25.18


CHESDIV SEMI
D=262' 5"CHAIN
TENS FORC AT SHIP CBL #1
TENS FORC AT SHIP (10^5 LBS)
3.22
2.70
2.17
1.12
12.72
25.18
TIME (SEC)


CHESDIV SEMI
D=262' 5"CHAIN
HORZ FORC AT ANCH CBL #1
HORZ FORC AT ANCH (10^5LBS)
TIME (SEC)
12.72
25.18
100.00

AD-A163 490 MOORING SYSTEM DESIGN AND TIME DOMAIN SIMULATION OF A SEMISUBMERSIBLE BUOY(U) WATT (BRIAN) ASSOCIATES INC HOUSTON TX SEP 83 N62477-84-D-0165

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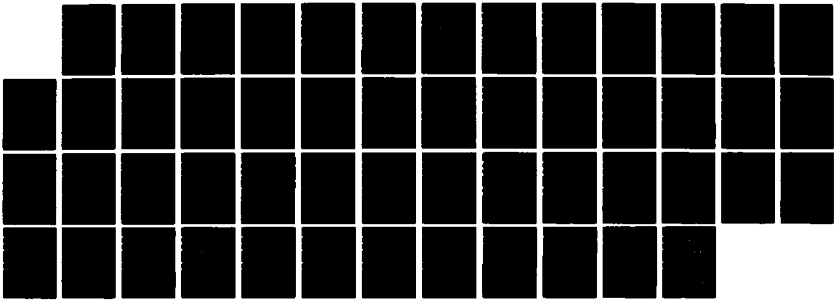
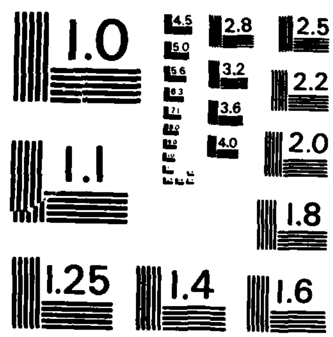
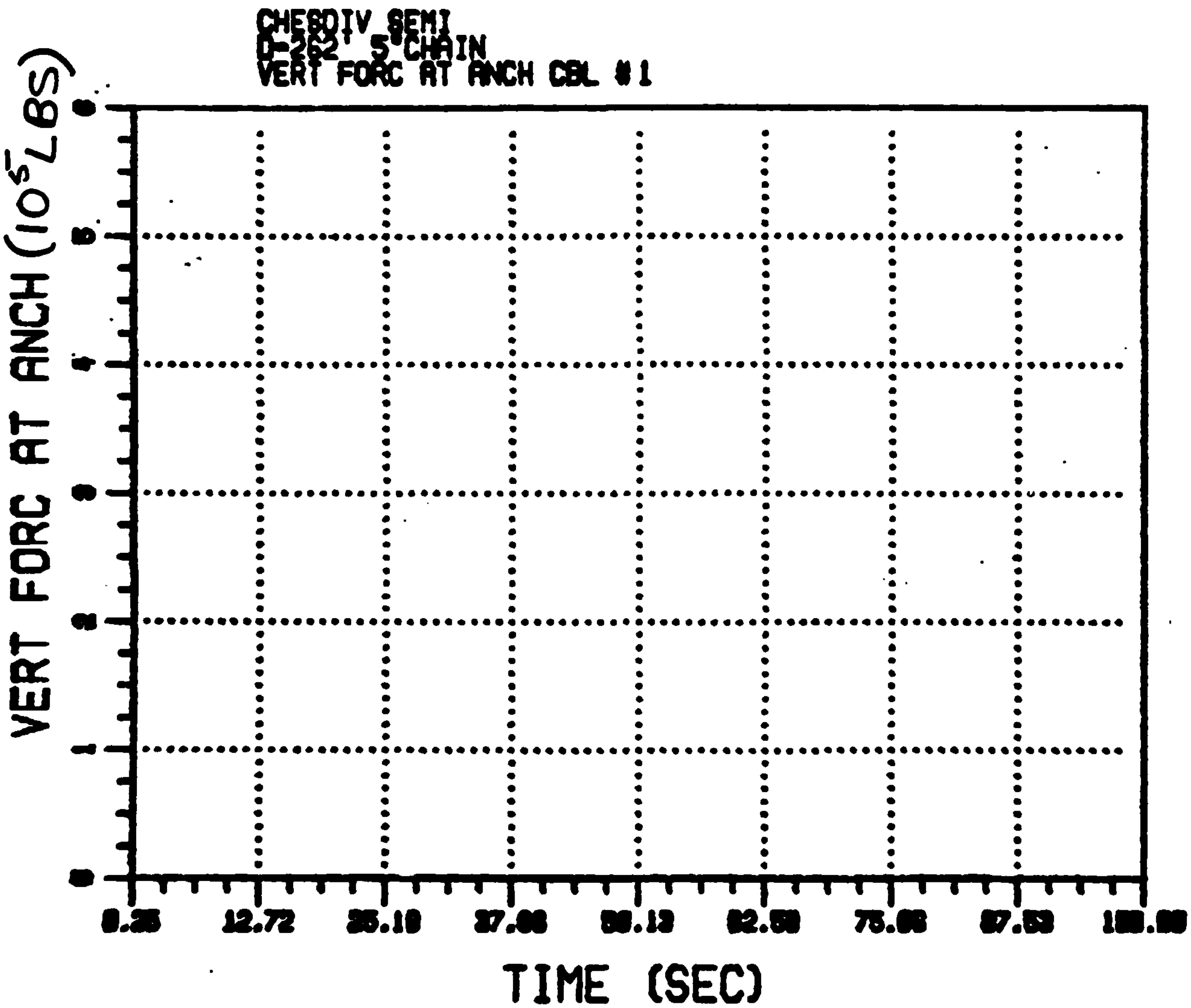
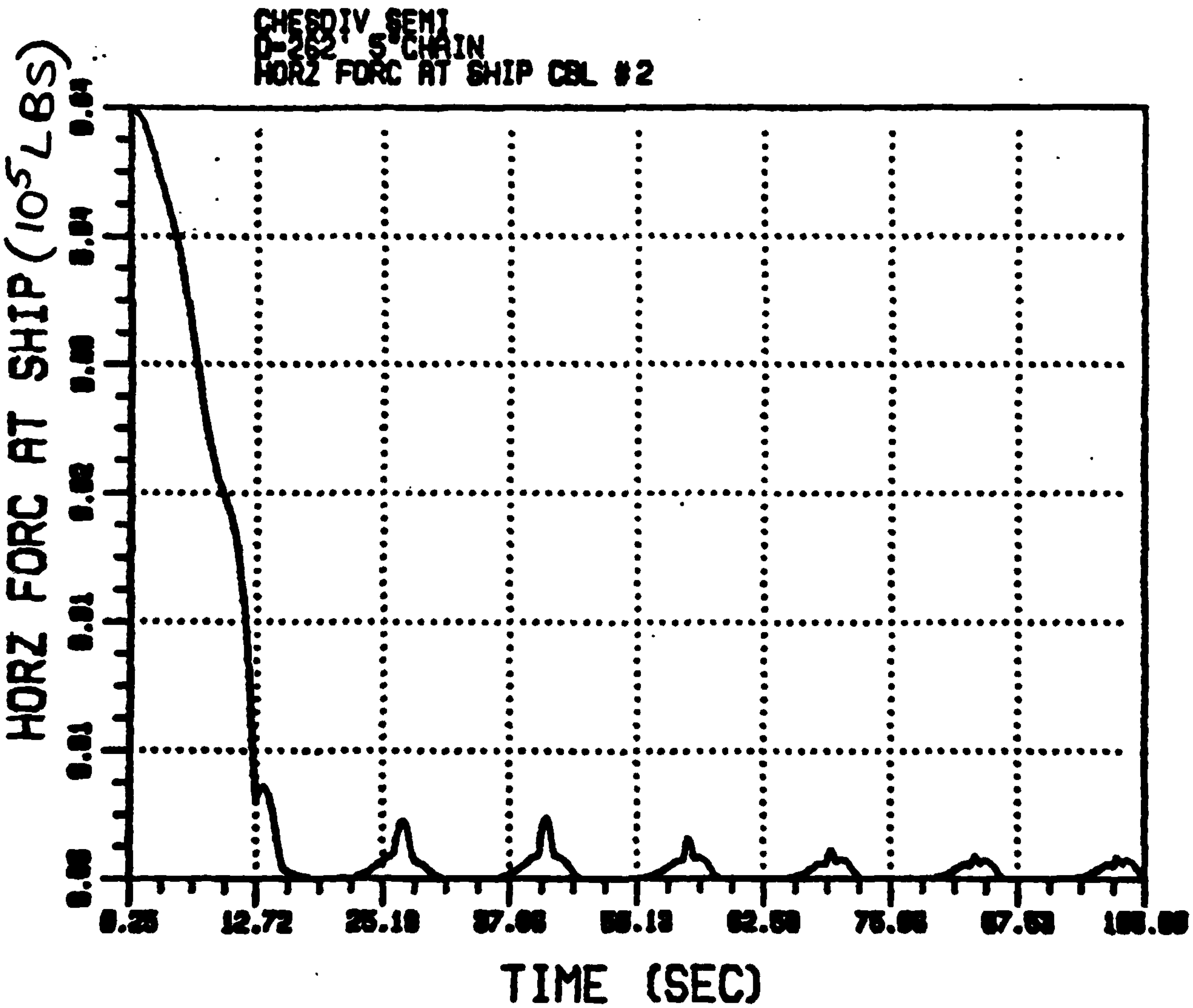
UNCLASSIFIED F/G 13/2 NL



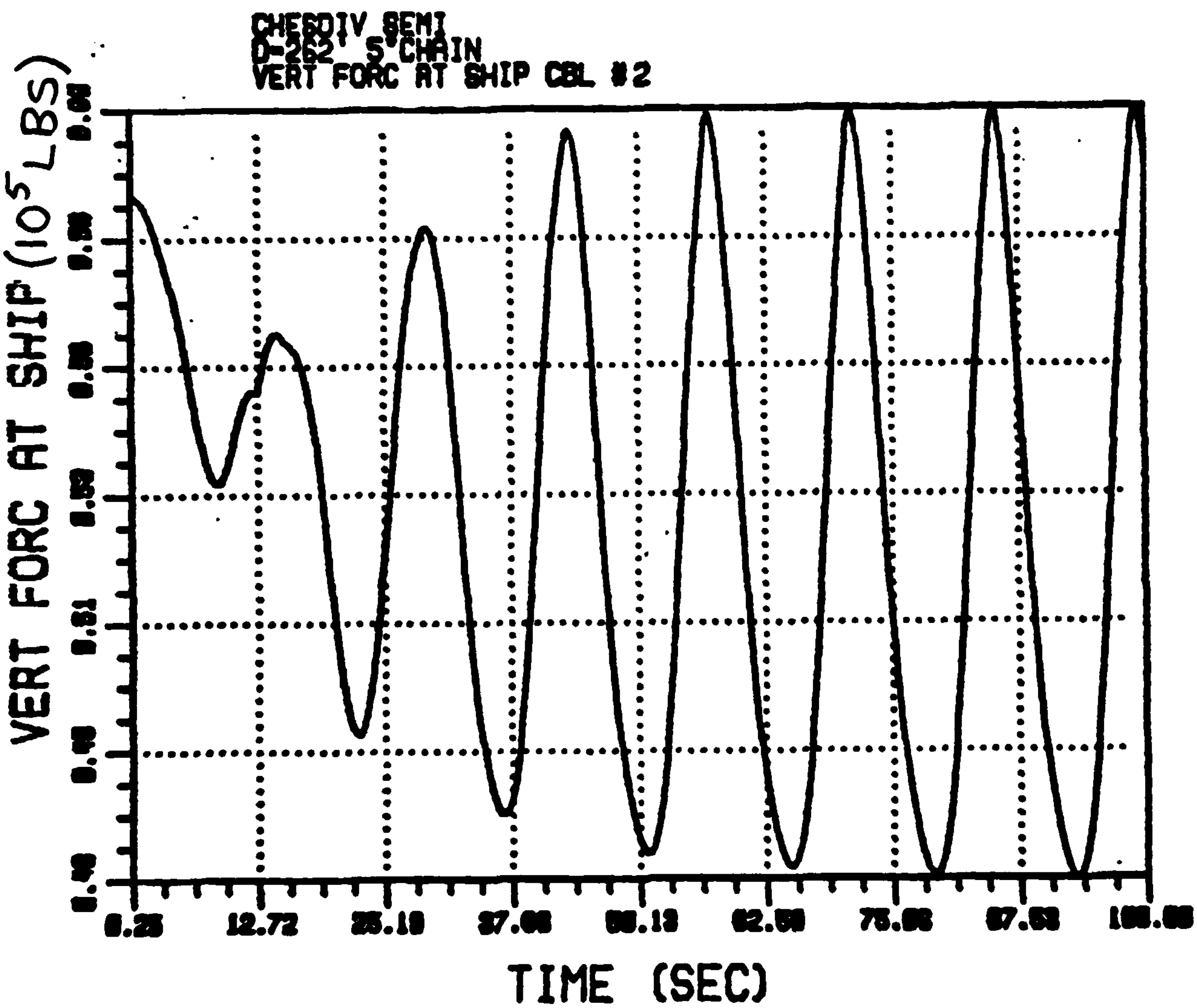

1.0
4.5
5.0
5.6
6.3
7.1
8.0
9.0
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

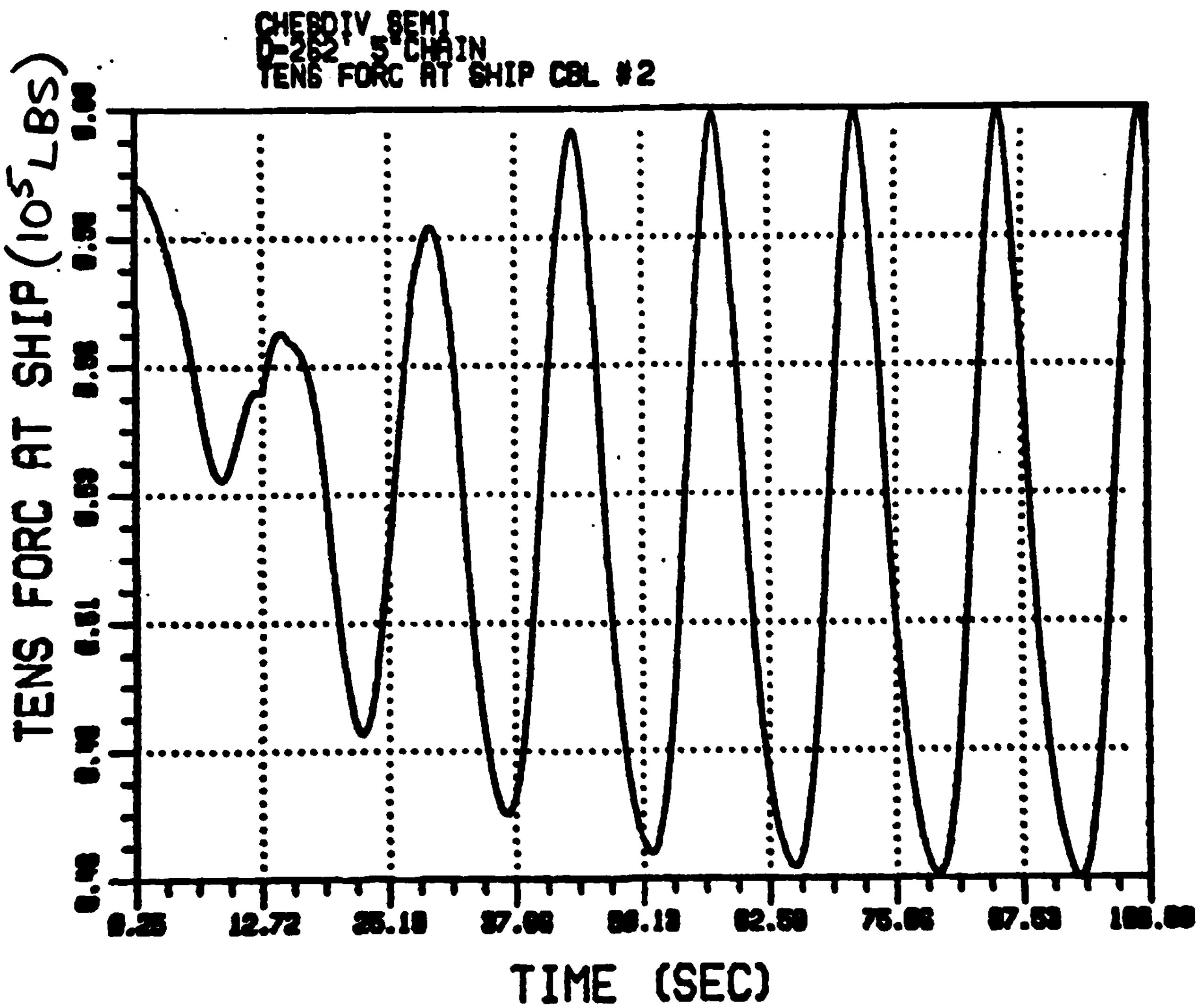


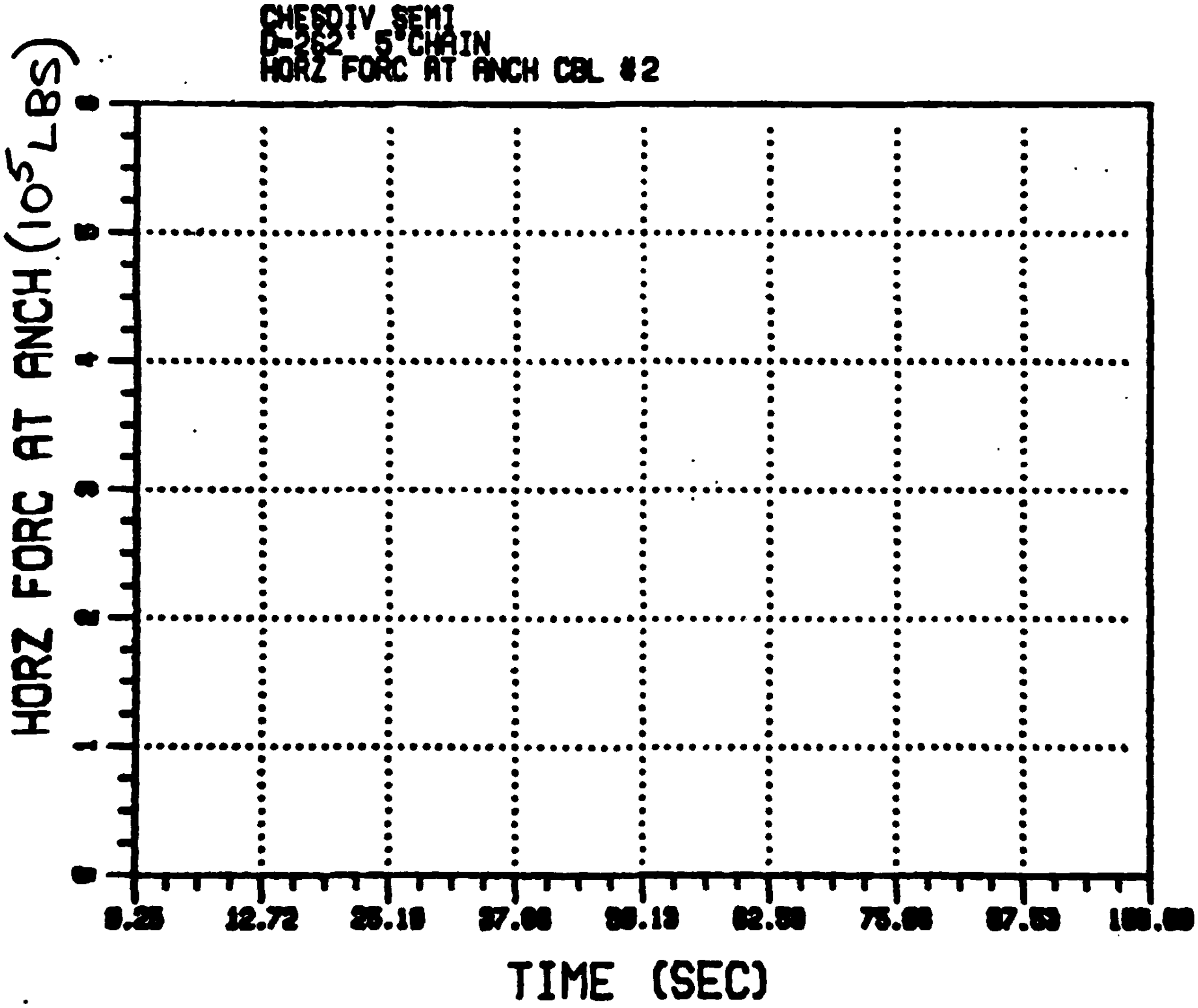
CHESDIV SEMI
VERT FORC AT ANCH CBL #1
VERT FORC AT ANCH (10^5 LBS)
12.72
25.19
TIME (SEC)



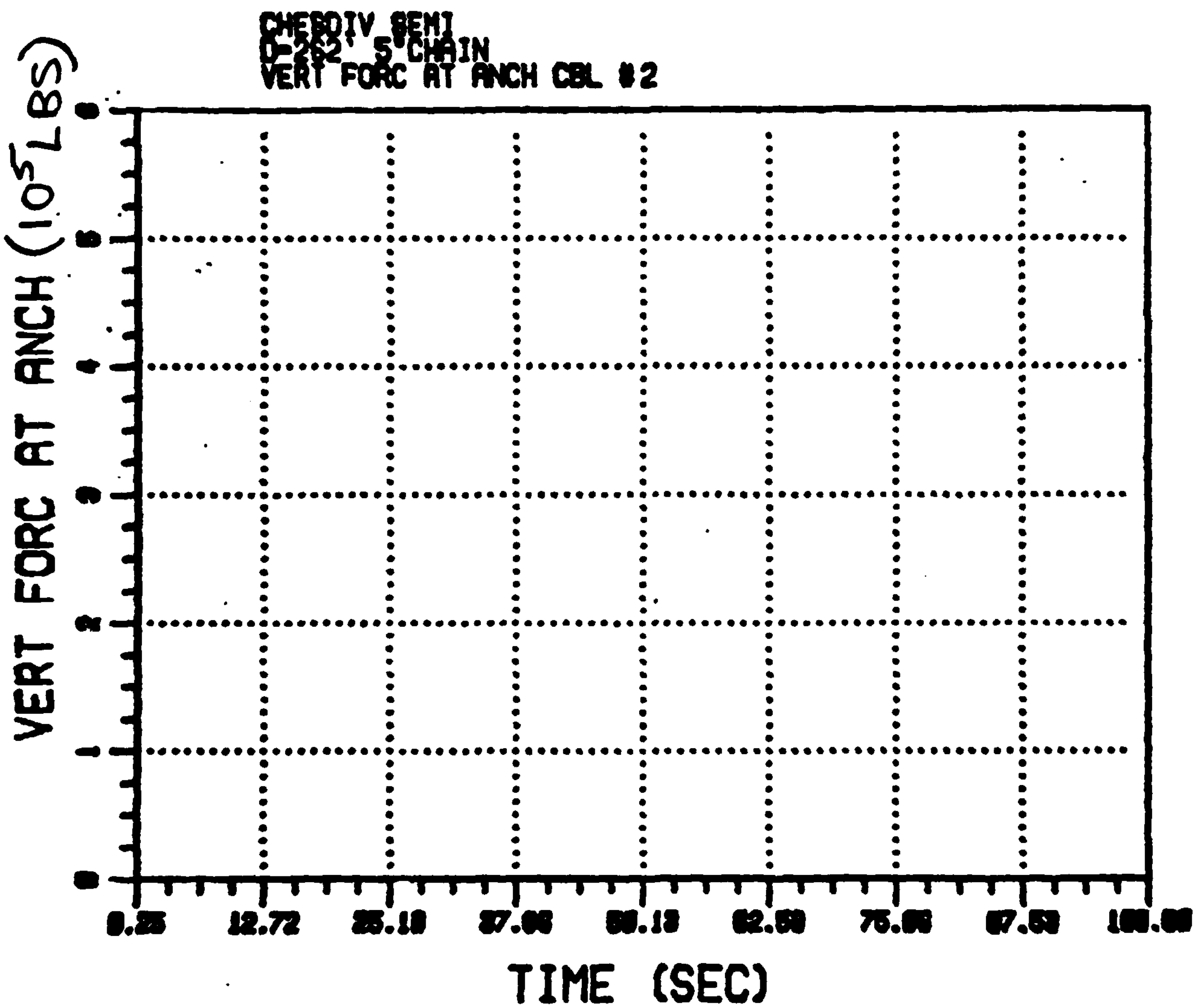
CHESDIV SEMI
D=262' 5"CHAIN
HORZ FORC AT SHIP CBL #2
HORZ FORC AT SHIP (10^5LBS)
12.72
TIME (SEC)


CHESDIV SEMI
D-262' 5"CHAIN
VERT FORC AT SHIP CBL #2
VERT FORC AT SHIP (10^5 LBS)
0.25
12.72
TIME (SEC)


CHEBDIV SEMI
D=262' 5"CHAIN
TENS FORC AT SHIP CBL #2
TENS FORC AT SHIP (10^5 LBS)
0.25
12.72
25.18
TIME (SEC)



CHESDIV SEMI
D=262' 5"CHAIN
HORZ FORC AT ANCH CBL #2
HORZ FORC AT ANCH (10^5 LBS)
TIME (SEC)
12.72
25.19


CHESDIV SEMI
D=262' 5" CHAIN
VERT FORC AT ANCH CBL #2
VERT FORC AT ANCH (10^5 LBS)
12.72
TIME (SEC)

SUMMARY OF RESULTS

EFFECTIVE WATER DEPTH = 262 FT

DESIGN WAVE HEIGHT (FT) = 72.0
WAVE PERIOD (SEC) = 14.0
MAX CREST ELEVATION (FT) = +42.03
MIN TROUGH ELEVATION (FT) = -29.85
MEAN ELEVATION (FT) = +6.08

MAX/MIN SURGE OFFSET (FT) = -149.28/-74.65
MEAN SURGE OFFSET (FT) = -112.0
MAX 1st ORDER MOTIONS (FT) = ± 37.3

MAX/MIN HEAVE OFFSET (FT) = -35.14/23.90
MEAN HEAVE OFFSET (FT) = -5.62
MAX 1st ORDER MOTION (FT) = ± 29.5

MAX/MIN PITCH ANGLE (DEG) = 11.87/-23.55
MEAN PITCH ANGLE (DEG) = -5.84
MAX 1st ORDER MOTION (DEG) = ± 17.7

MAX HORIZONTAL FORCE @ VESSEL (KIPS) = 325
MIN HORIZONTAL FORCE @ VESSEL (KIPS) = 31
MEAN HORIZONTAL FORCE @ VESSEL (KIPS) = 178

MAX VERTICAL FORCE @ VESSEL (KIPS) = 188
MIN VERTICAL FORCE @ VESSEL (KIPS) = 80
MEAN VERTICAL FORCE @ VESSEL (KIPS) = 134

MAX TENSION @ VESSEL (KIPS) = 376
MIN TENSION @ VESSEL (KIPS) = 80
MEAN TENSION @ VESSEL (KIPS) = 228

MAX HORZ. FORCE @ ANCHOR (KIPS) = 175
MIN HORZ. FORCE @ ANCHOR (KIPS) = 0

MAX VERTICAL FORCE @ ANCHOR (KIPS) = 0
MIN VERTICAL FORCE @ ANCHOR (KIPS) = 0

CHAIN DIAMETER (IN) = 5.0
LENGTH OF CHAIN (FT) = 2,000
LOCATION OF ANCHOR (FT) = 1,800
PROOF LOAD (KIPS) = 1,203

(PEAK TENSION / PROOF LOAD) x 100 = 31.26 %

APPENDIX A.3

WATER DEPTH	=	150 FT
EFFECTIVE DEPTH	=	162 FT
WAVE HEIGHT	=	64 FT
WAVE PERIOD	=	13.6 SEC
CURRENT	=	3 KN
WIND	=	150 KN
MOORING CHAIN	=	5 IN

ITEM	WEIGHT (S.TONS)
SEMISUBMERSIBLE + PAYLOAD	65.1
MOORING SYSTEM VERTICAL COMPONENT	69.4
BALLAST	119.9
TOTAL DISPLACEMENT	254.4

SEMISUBMERSIBLE WEIGHT DISTRIBUTION

DEPTH = 162 FT

**** CALCULATED DISPLACEMENT PROPERTIES ****

DISPLACEMENT	=	0.49987E 06
CENTER OF BUOYANCY ALONG X-AXIS	=	0.00
CENTER OF BUOYANCY ALONG Y-AXIS	=	0.00
CENTER OF BUOYANCY ALONG Z-AXIS	=	-19.89

**** STRUCTURAL INPUT PROPERTIES ****

STRUCTURAL WEIGHT	=	0.37039E 06
ROLL RADIUS OF GYRATION	=	24.50
PITCH RADIUS OF GRYRATION	=	24.50
YAW RADIUS OF GRYRATION	=	30.30
CENTER OF GRAVITY ALONG X-AXIS	=	0.00
CENTER OF GRAVITY ALONG Y-AXIS	=	0.00
CENTER OF GRAVITY ALONG Z-AXIS	=	-18.50

**** WATER INPUT PROPERTIES ****

MASS DENSITY OF WATER	=	1.99
ACCELERATION OF GRAVITY	=	32.17
WAVE HEIGHT	=	64.00
WAVE PERIOD	=	13.60
WATER DEPTH	=	162.00
ANGLE OF ATTACK IN DEGREES	=	180.00

FREQUENCY DOMAIN RESULTS
UNITS: LBS, FEET

**** CALCULATED WATERPLANE PROPERTIES ****

WATERPLANE AREA	=	94.51
CENTER OF AREA ALONG X-AXIS	=	0.00
CENTER OF AREA ALONG Y-AXIS	=	-0.00
WATERPLANE INERTIA ABOUT X-AXIS	=	0.66787E 05
WATERPLANE INERTIA ABOUT Y-AXIS	=	0.66783E 05
METACENTRIC HEIGHT IN ROLL	=	7.17
METACENTRIC HEIGHT IN PITCH	=	7.17

**** CENTERS ARE IN ORIGINAL SYSTEM ****

**** INERTIAS ARE ABOUT AXES THRU CG ***

BU[illegible]ASS [illegible]IX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.11512091E 05	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00
SWAY	0.00000000E 00	0.11512091E 05	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00
HEAVE	0.00000000E 00	0.00000000E 00	0.11512091E 05	0.00000000E 00	0.00000000E 00	0.00000000E 00
ROLL	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.69101323E 07	0.00000000E 00	0.00000000E 00
PITCH	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.69101323E 07	0.00000000E 00
YAW	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.10569135E 08

ADDED MASS MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.96193757E 04	-0.20929747E-09	-0.64801498E-11	-0.12369128E-08	0.49247889E 04	0.24875956E-01
SWAY	-0.20929747E-09	0.96179669E 04	-0.34106051E-11	-0.49326190E 04	-0.11332304E-08	0.22230983E 02
HEAVE	-0.64801498E-11	-0.34106051E-11	0.12226625E 05	0.24875950E-01	-0.31666512E 02	-0.13096724E-09
ROLL	-0.12369128E-08	-0.49326190E 04	0.24875950E-01	0.47673519E 07	-0.69180543E 00	-0.69891130E 02
PITCH	0.49247889E 04	-0.11332304E-08	-0.31666512E 02	-0.69180545E 00	0.47666549E 07	-0.13889003E 00
YAW	0.24875956E-01	0.22230983E 02	-0.13096724E-09	-0.69891130E 02	-0.13889003E 00	0.95184866E 07

HYDROSTATIC STIFFNESS MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00
SWAY	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00
HEAVE	0.00000000E 00	0.00000000E 00	0.60525515E 04	-0.46596940E-09	-0.20175172E 02	0.00000000E 00
ROLL	0.00000000E 00	0.00000000E 00	-0.46596940E-09	0.35821314E 07	-0.15532313E-11	0.00000000E 00
PITCH	0.00000000E 00	0.00000000E 00	-0.20175172E 02	-0.15532313E-11	0.35818814E 07	0.00000000E 00
YAW	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00

MOORING STIFFNESS MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.85795176E 02	-0.11368684E-12	0.11557187E 00	-0.29103830E-10	0.35933618E 04	0.71054274E-14
SWAY	-0.11368684E-12	0.85643898E 02	0.00000000E 00	-0.35930892E 04	-0.14551915E-10	-0.50693722E 01
HEAVE	0.11557187E 00	0.00000000E 00	0.10958036E 04	-0.24156179E-08	-0.11916092E 02	0.00000000E 00
ROLL	-0.29103830E-10	-0.35930892E 04	-0.24156179E-08	0.93317932E 06	-0.49360096E-07	-0.16293887E 02
PITCH	0.35933618E 04	-0.14551915E-10	-0.11916092E 02	-0.49360096E-07	0.93305849E 06	0.42351647E-21
YAW	0.71054274E-14	-0.50693722E 01	0.00000000E 00	-0.16293887E 02	0.42351647E-21	0.57955442E 00

MODE SHAPE MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.99999968E 00	-0.32476703E-07	0.25984519E-04	0.54871196E-03	0.20446762E 00	0.40041409E-11
SWAY	0.32458959E-07	0.99999968E 00	-0.25146422E-08	-0.20409445E 00	0.54757864E-03	0.61277104E-01
HEAVE	-0.20004639E-04	0.11693253E-10	0.10000000E 01	-0.30268747E-04	-0.95522780E-02	-0.57342084E-16
ROLL	0.26434629E-10	0.79957808E-03	0.74889658E-08	0.97894752E 00	-0.26263595E-02	0.52363478E-04
PITCH	-0.79971892E-03	0.25495184E-10	0.22528948E-04	0.26269066E-02	0.97882304E 00	-0.35950114E-14
YAW	-0.12460390E-08	-0.65681742E-04	0.13437180E-12	0.17117015E-05	0.19224755E-08	0.99812079E 00

NATURAL PERIOD IN SURGE= 0.10029301E 03
NATURAL PERIOD IN SWAY = 0.10038061E 03
NATURAL PERIOD IN HEAVE= 0.11449999E 02
NATURAL PERIOD IN ROLL = 0.10104011E 02
NATURAL PERIOD IN PITCH= 0.10104122E 02
NATURAL PERIOD IN YAW = 0.54450248E 05

PERIOD	LENGTH	SURGE	PHASE	SWAY	PHASE	HEAVE	PHASE	ROLL	PHASE	PITCH	PHASE	YAW	PHASE

WAVE PERIOD= 13.60

	INERTIAL FORCES AMPLITUDE	INERTIAL FORCES PHASE SHIFT	FROUDE-KRYLOV FORCES AMPLITUDE	FROUDE-KRYLOV FORCES PHASE SHIFT	VICOUS DRAG FORCES AMPLITUDE	VICOUS DRAG FORCES PHASE SHIFT
SURGE	0.67453286E 05	0.91897717E 02	0.10590168E 06	0.90121152E 02	0.31368204E 06	-0.17874524E 03
SWAY	0.99707856E-03	-0.10244432E 02	0.11078571E-02	-0.10244705E 02	0.49305847E-02	0.91026244E 02
HEAVE	0.66292380E 05	-0.17999808E 03	0.11909699E 06	0.80431734E-01	0.38106549E 06	-0.88946012E 02
ROLL	0.12971892E 00	0.16749820E 03	0.14413230E 00	0.16749817E 03	0.36574366E 00	-0.10684382E 03
PITCH	0.11545768E 06	-0.86390239E 02	0.66011221E 06	0.84626680E 02	0.39134236E 06	-0.20983178E 02
YAW	0.17029844E 00	0.75856810E 02	0.18922030E 00	0.75856918E 02	0.82875876E 00	0.16514467E 03

DAMPING MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.20708204E 05	0.63942283E-04	-0.32216599E 03	0.58581700E-03	0.35945622E 05	0.55845665E-01
SWAY	0.63942283E-04	0.18631578E 05	-0.81068802E-05	-0.41497101E 05	-0.28042091E-03	0.28016142E 05
HEAVE	-0.32216599E 03	-0.81068802E-05	0.32061945E 05	0.32989153E-01	0.19207504E 05	-0.30540205E-03
ROLL	0.58581700E-03	-0.41497101E 05	0.32989153E-01	0.12344226E 08	-0.11208218E 01	0.65172077E 05
PITCH	0.35945622E 05	-0.28042091E-03	0.19207504E 05	-0.11208218E 01	0.12860071E 08	-0.31283529E 00
YAW	0.55845665E-01	0.28016142E 05	-0.30540205E-03	0.65172077E 05	-0.31283530E 00	0.18136669E 08

CATENARY MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.10430518E 03	-0.22737368E-12	-0.71379521E 01	-0.21827873E-10	0.39293320E 04	-0.34678926E-11
SWAY	-0.22737368E-12	0.85443949E 02	0.00000000E 00	-0.35663823E 04	-0.72759576E-11	0.12309055E 00
HEAVE	-0.71379521E 01	0.00000000E 00	0.10958036E 04	-0.14551915E-09	-0.12141379E 02	-0.45927706E-11
ROLL	-0.21827873E-10	-0.35663823E 04	-0.14551915E-09	0.93127633E 06	-0.37252903E-08	-0.14513919E 02
PITCH	0.39293320E 04	-0.72759576E-11	-0.12141379E 02	-0.37252903E-08	0.93310905E 06	-0.14169643E-09
YAW	-0.34678926E-11	0.12309055E 00	-0.45927706E-11	-0.14513919E 02	-0.14169643E-09	0.16242830E-02

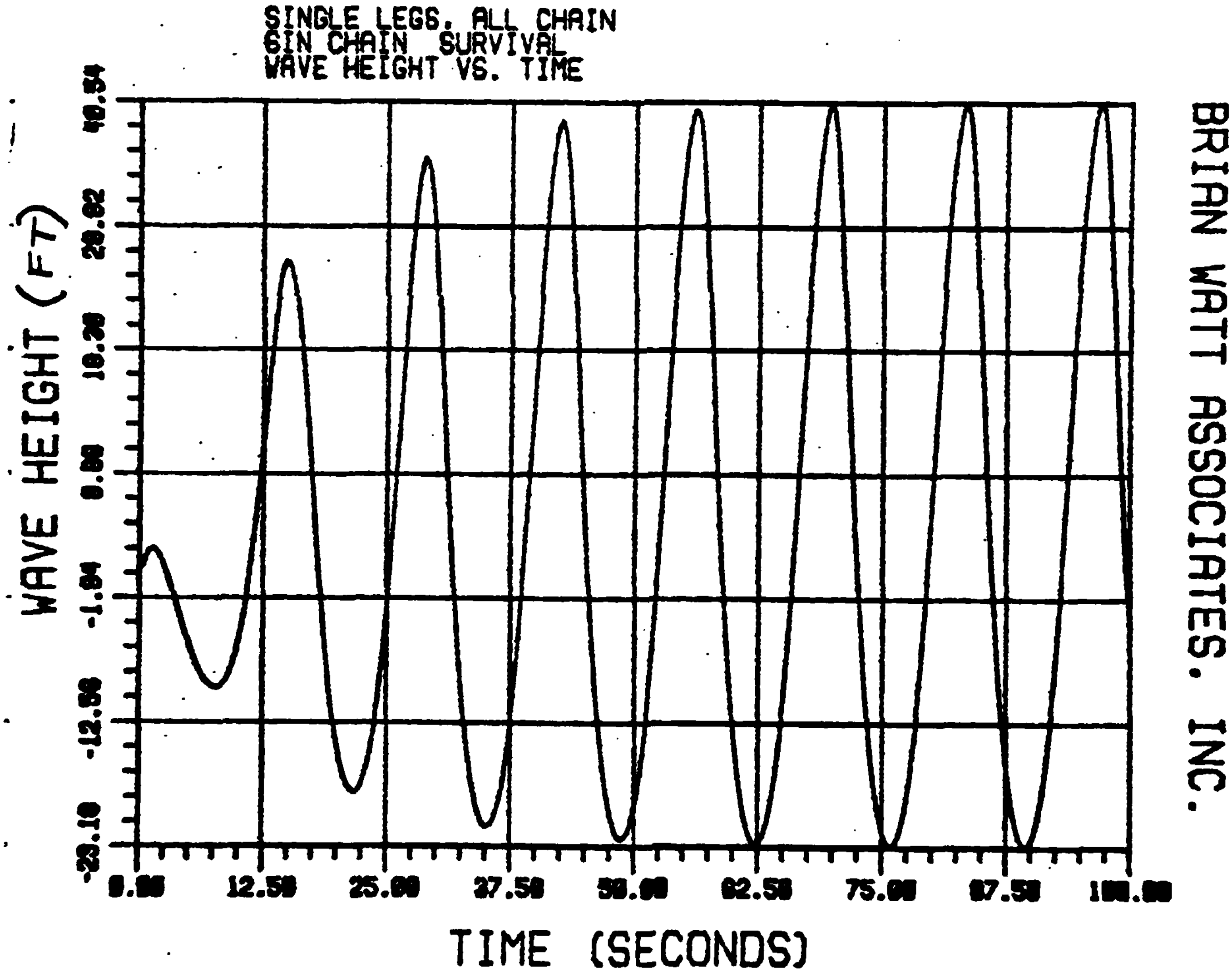
MOORING SYSTEM USED: 6" GRADE 2 CHAIN
LENGTH OF CHAIN = 3,000 FT
LOCATION OF ANCHOR = 2,850 FT

FORCES IN CATENARY LINES

PERIOD	ELEMENT	MIN HOR FOR AT SHP MAX HOR FOR AT SHP	MIN VER FOR AT SHP MAX VER FOR AT SHP	MIN TEN AT SHP MAX TEN AT SHP	MIN HOR FOR AT BOT MAX HOR FOR AT BOT	MIN VER FOR AT BOT MAX VER FOR AT BOT
13.60	1	0.79447407E 04	0.45053420E 05	0.45764226E 05	0.00000000E 00	0.00000000E 00
		0.10189311E 07	0.29462757E 06	0.10606725E 07	0.74225204E 06	0.00000000E 00
13.60	2	0.10000000E-05	0.38395587E 05	0.38395587E 05	0.00000000E 00	0.00000000E 00
		0.10000000E-05	0.53411883E 05	0.53411883E 05	0.00000000E 00	0.00000000E 00
13.60	3	0.10000000E-05	0.38395586E 05	0.38395586E 05	0.00000000E 00	0.00000000E 00
		0.10000000E-05	0.53411882E 05	0.53411882E 05	0.00000000E 00	0.00000000E 00

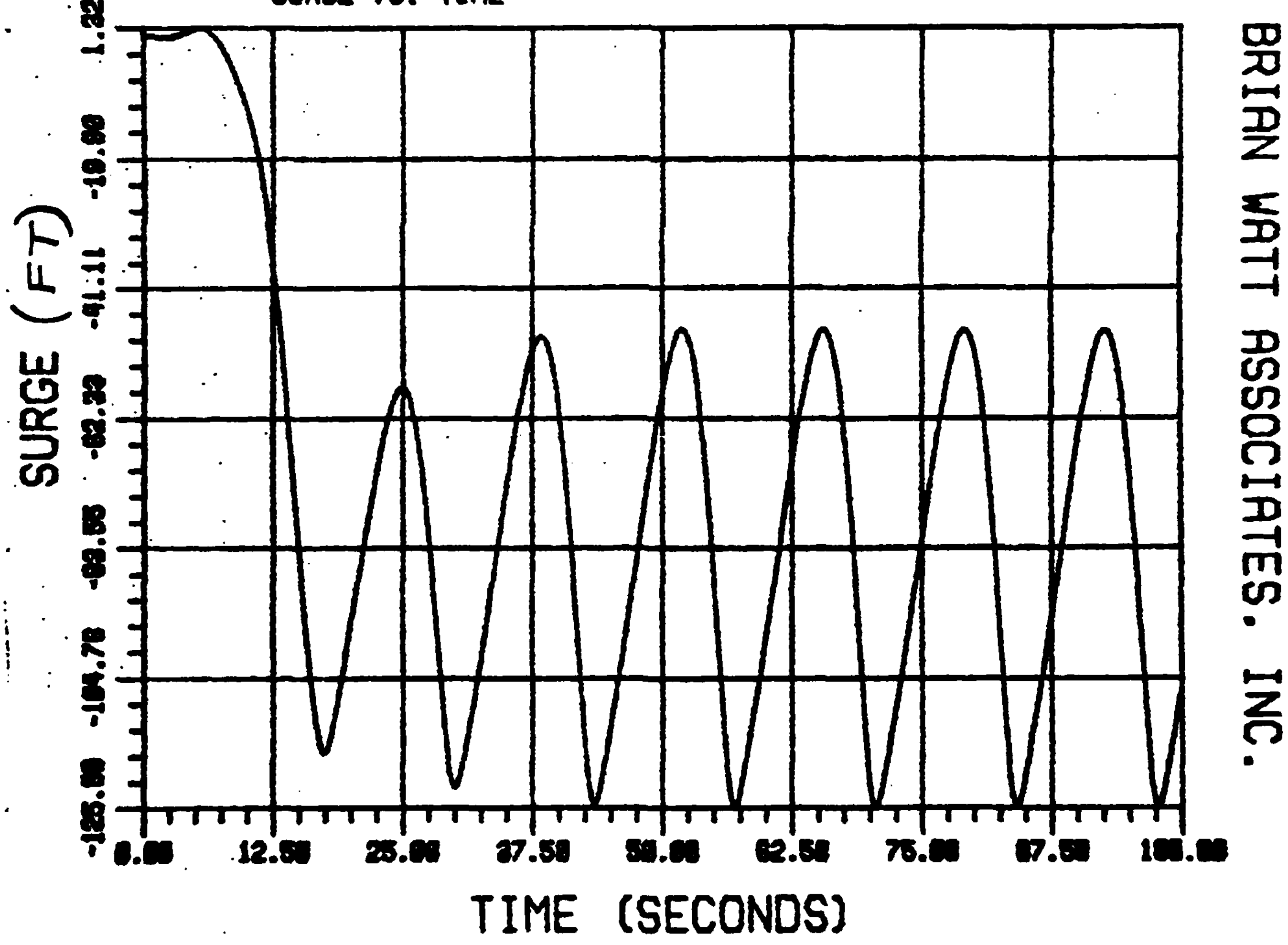
FORCES AT ANCHOR

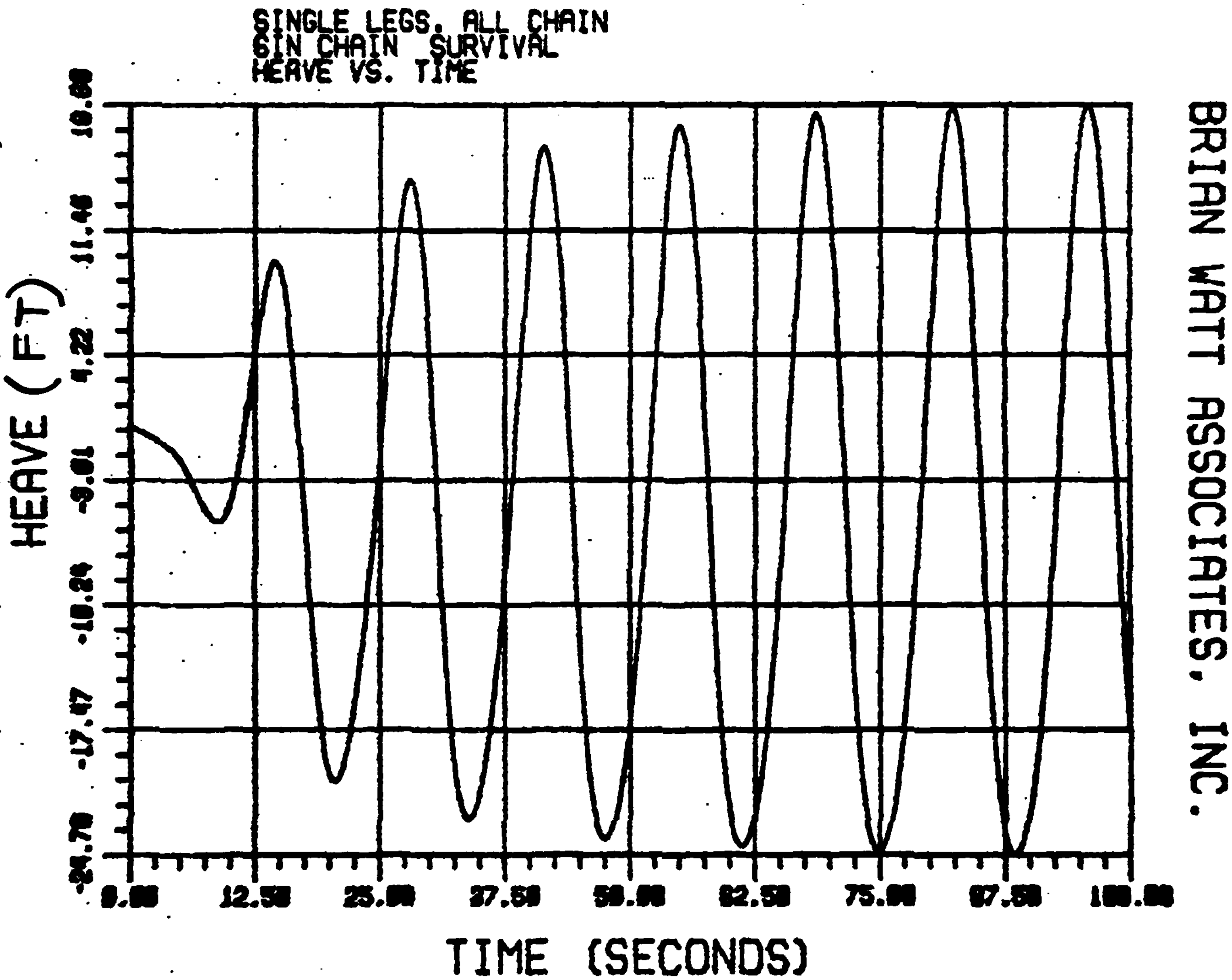
FORCES IN LBS.



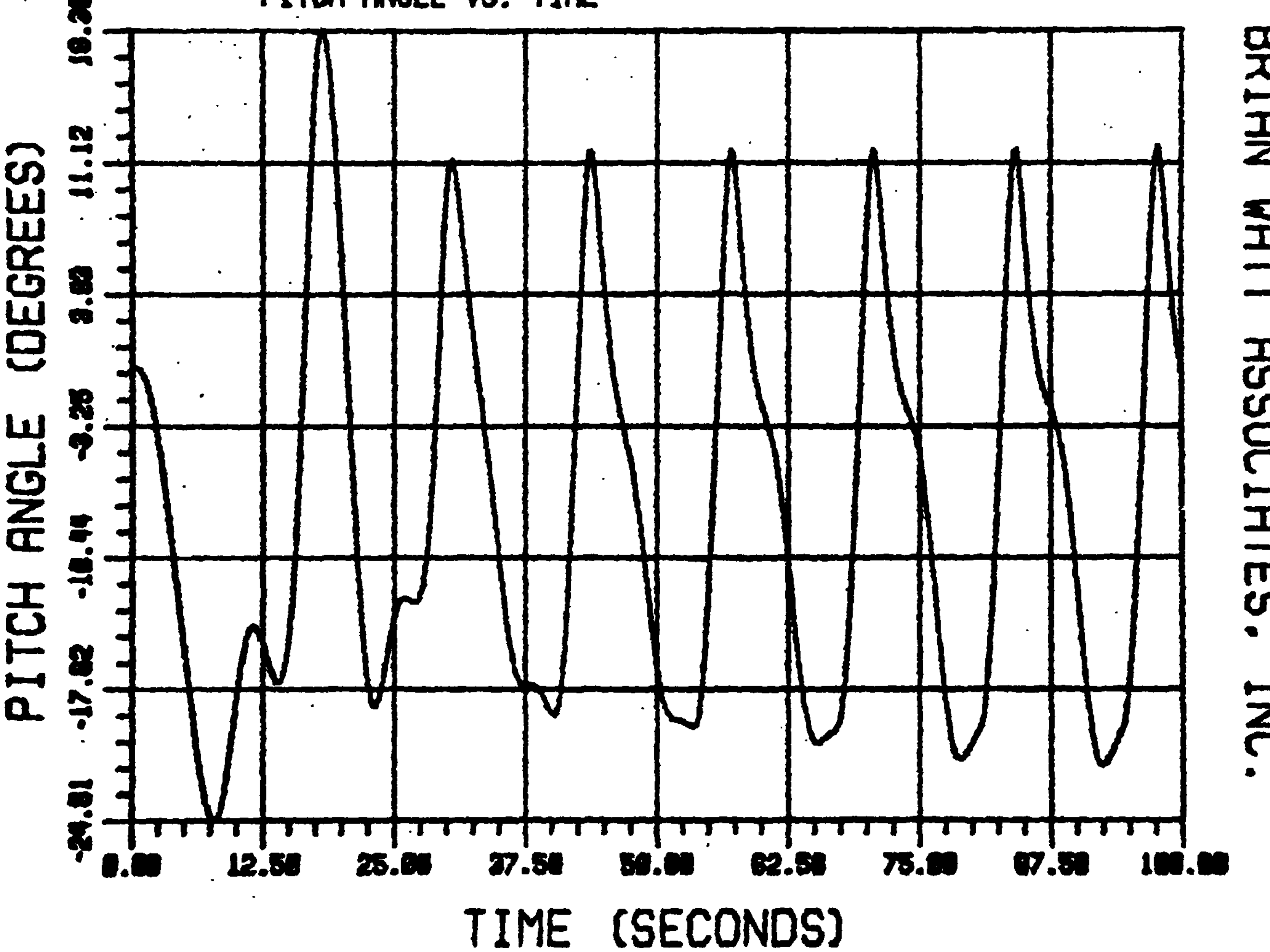
SINGLE LEGS, ALL CHAIN
6IN CHAIN SURVIVAL
WAVE HEIGHT VS. TIME
WAVE HEIGHT (FT)
TIME (SECONDS)
12.50
25.00
37.50
62.50
75.00
87.50
BRIAN WATT ASSOCIATES, INC.

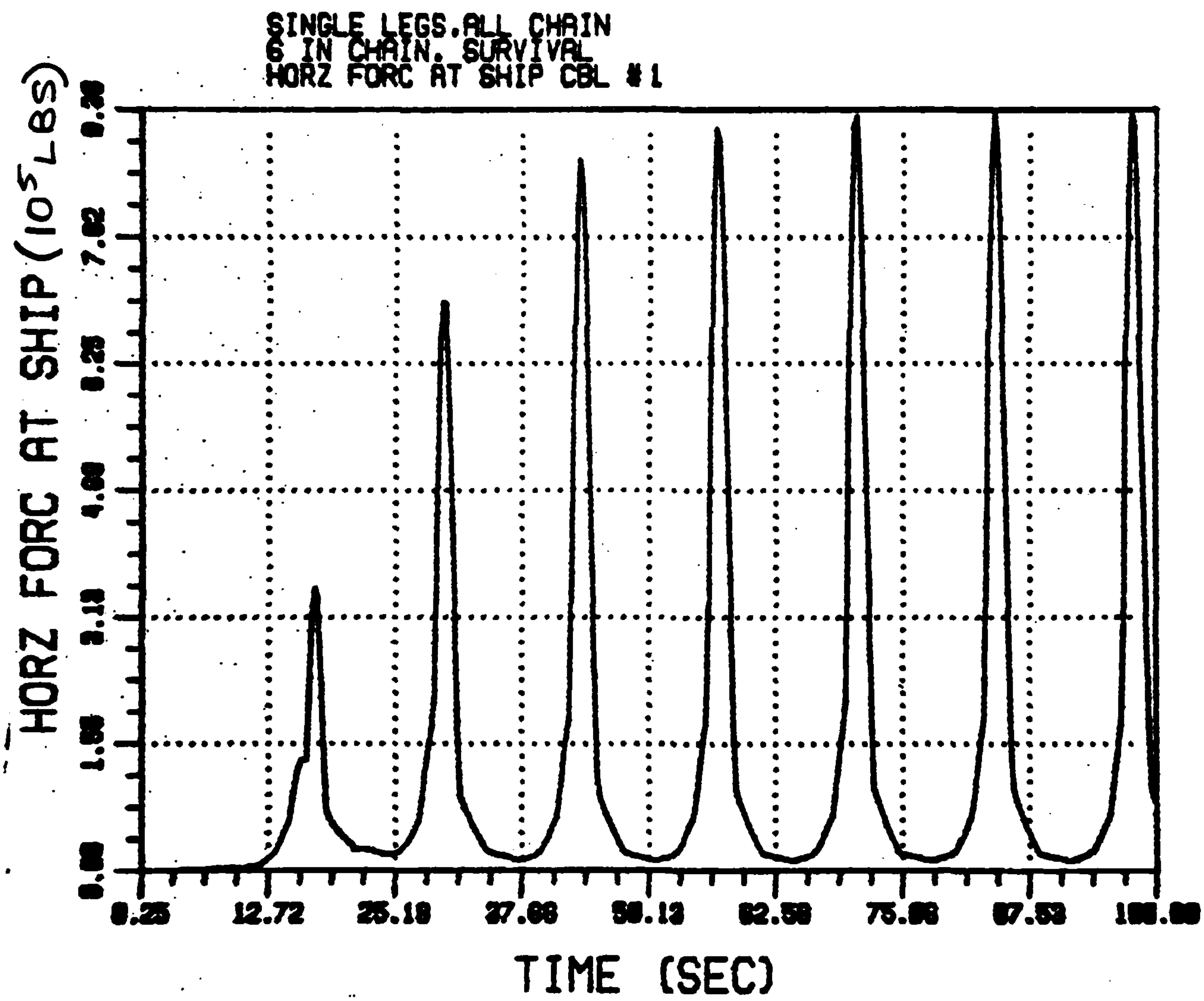
SINGLE LEGS. ALL CHAIN
6IN CHAIN SURVIVAL
SURGE VS. TIME



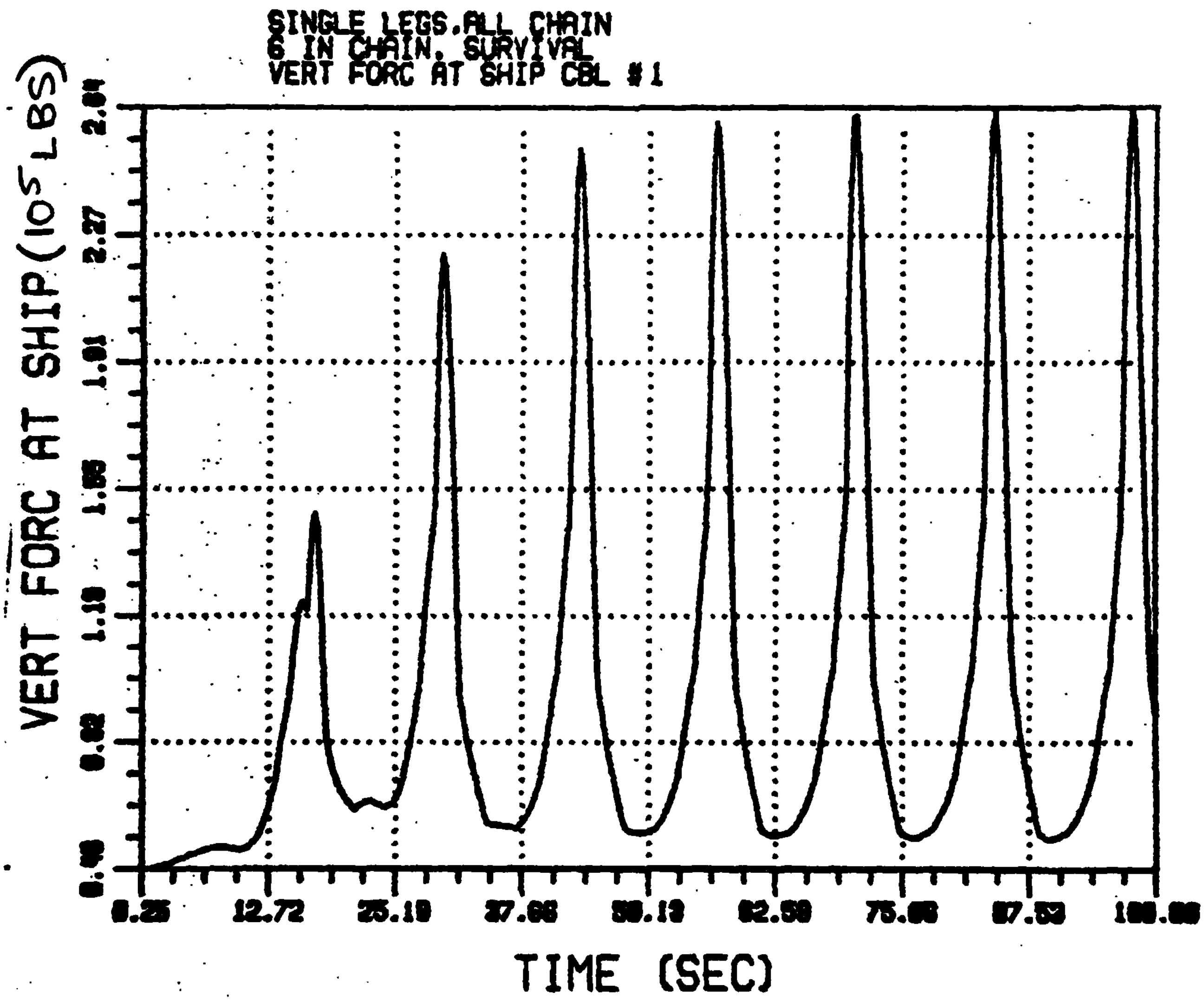

SINGLE LEGS, ALL CHAIN
6IN CHAIN SURVIVAL
HEAVE VS. TIME
HEAVE (FT)
TIME (SECONDS)
BRIAN WATT ASSOCIATES, INC.

SINGLE LEGS, ALL CHAIN
6IN CHAIN SURVIVAL
PITCH ANGLE VS. TIME

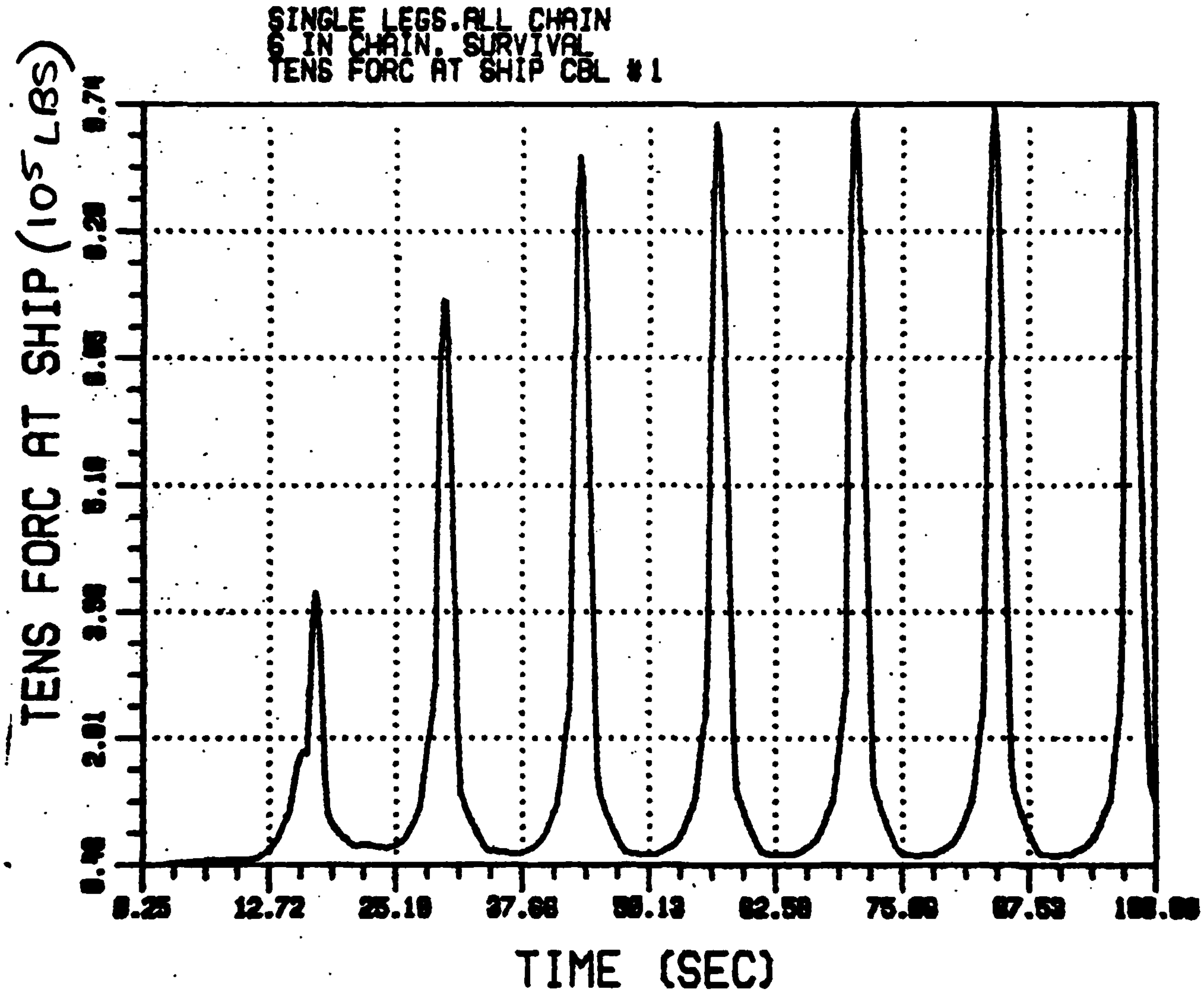




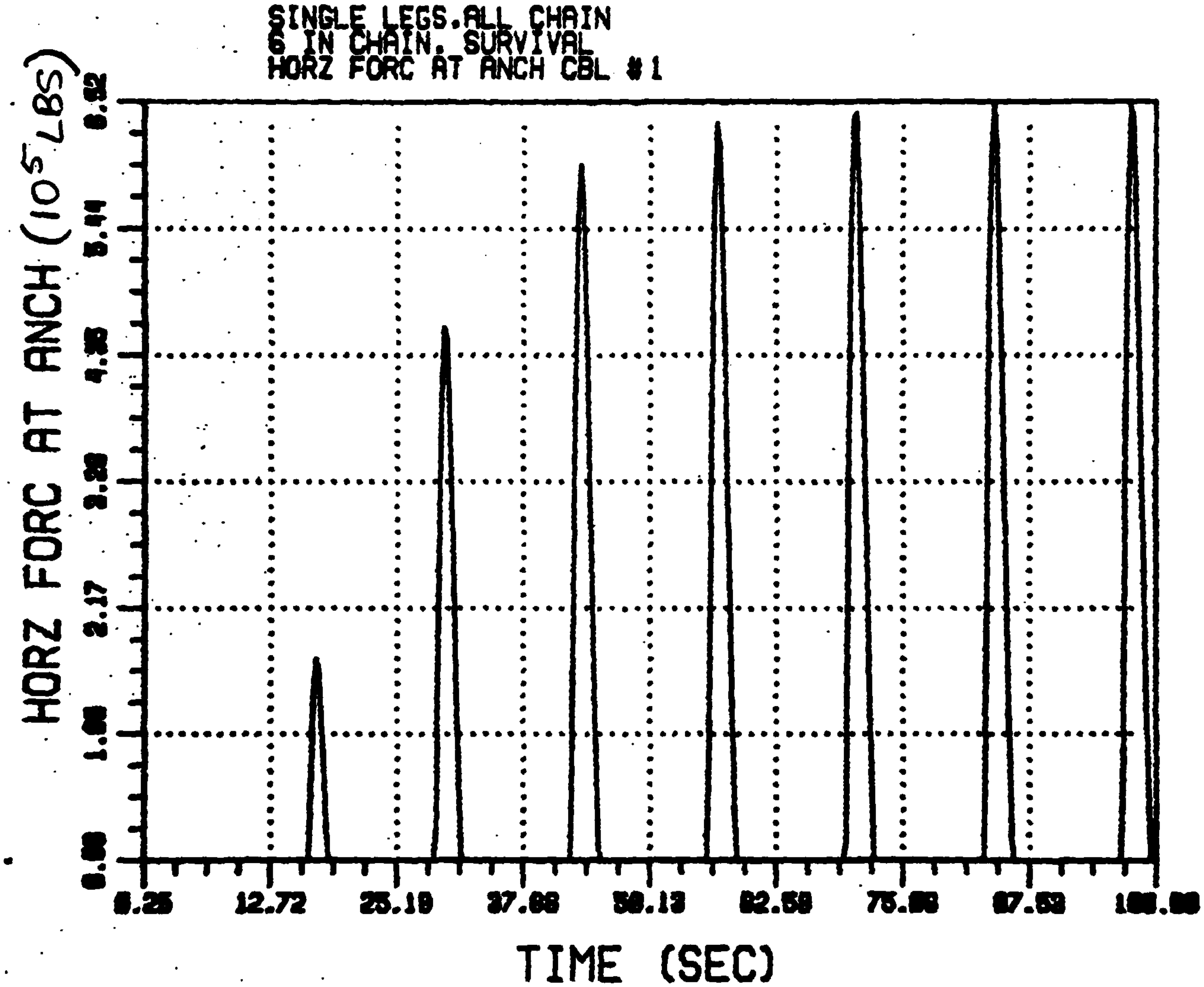
SINGLE LEGS.ALL CHAIN
6 IN CHAIN. SURVIVAL
HORZ FORC AT SHIP CBL #1
HORZ FORC AT SHIP (10^5 LBS)
12.72
TIME (SEC)



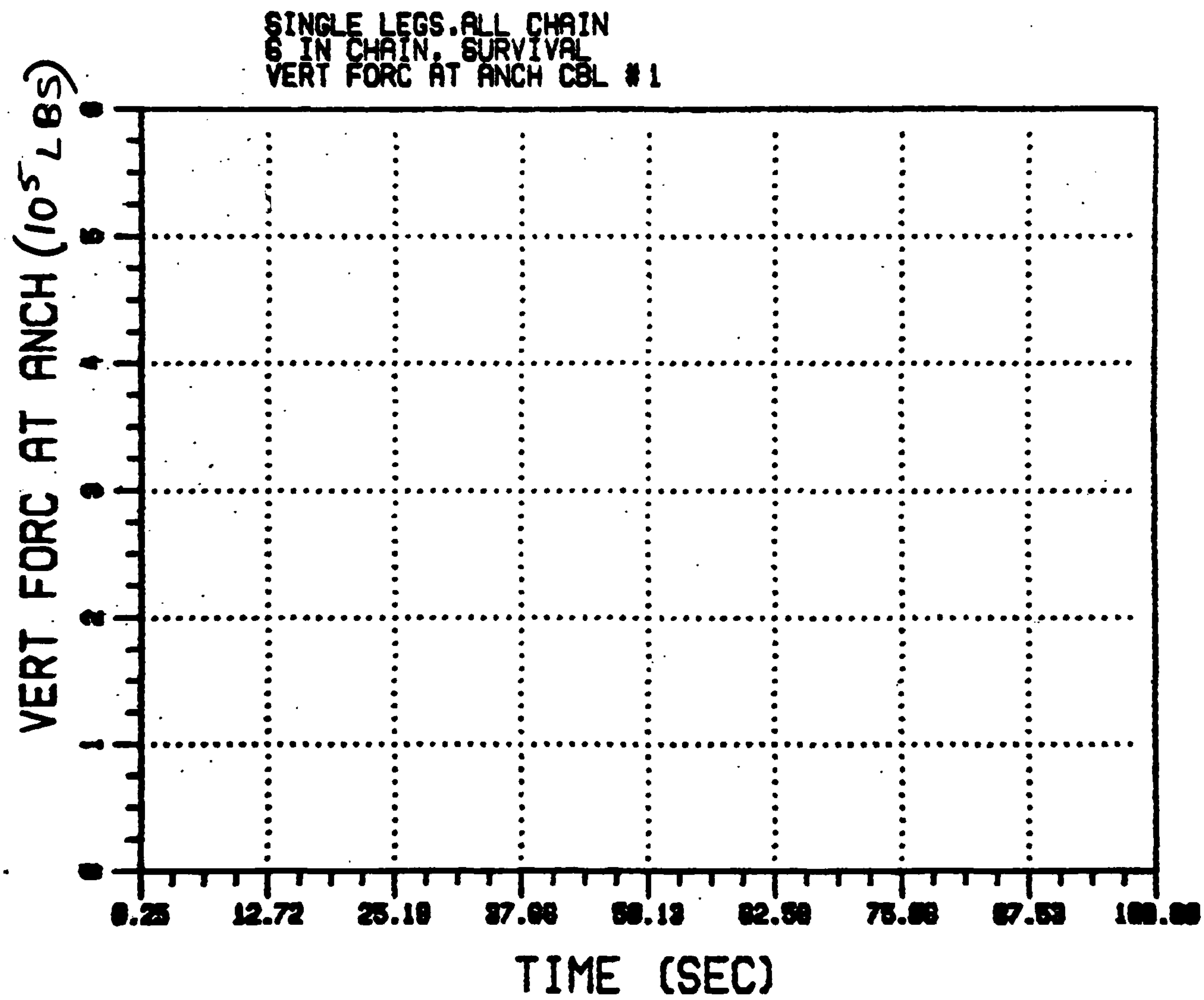
SINGLE LEGS,ALL CHAIN
6 IN CHAIN, SURVIVAL
VERT FORC AT SHIP CBL #1
VERT FORC AT SHIP(10^5 LBS)
TIME (SEC)
12.72
25.19



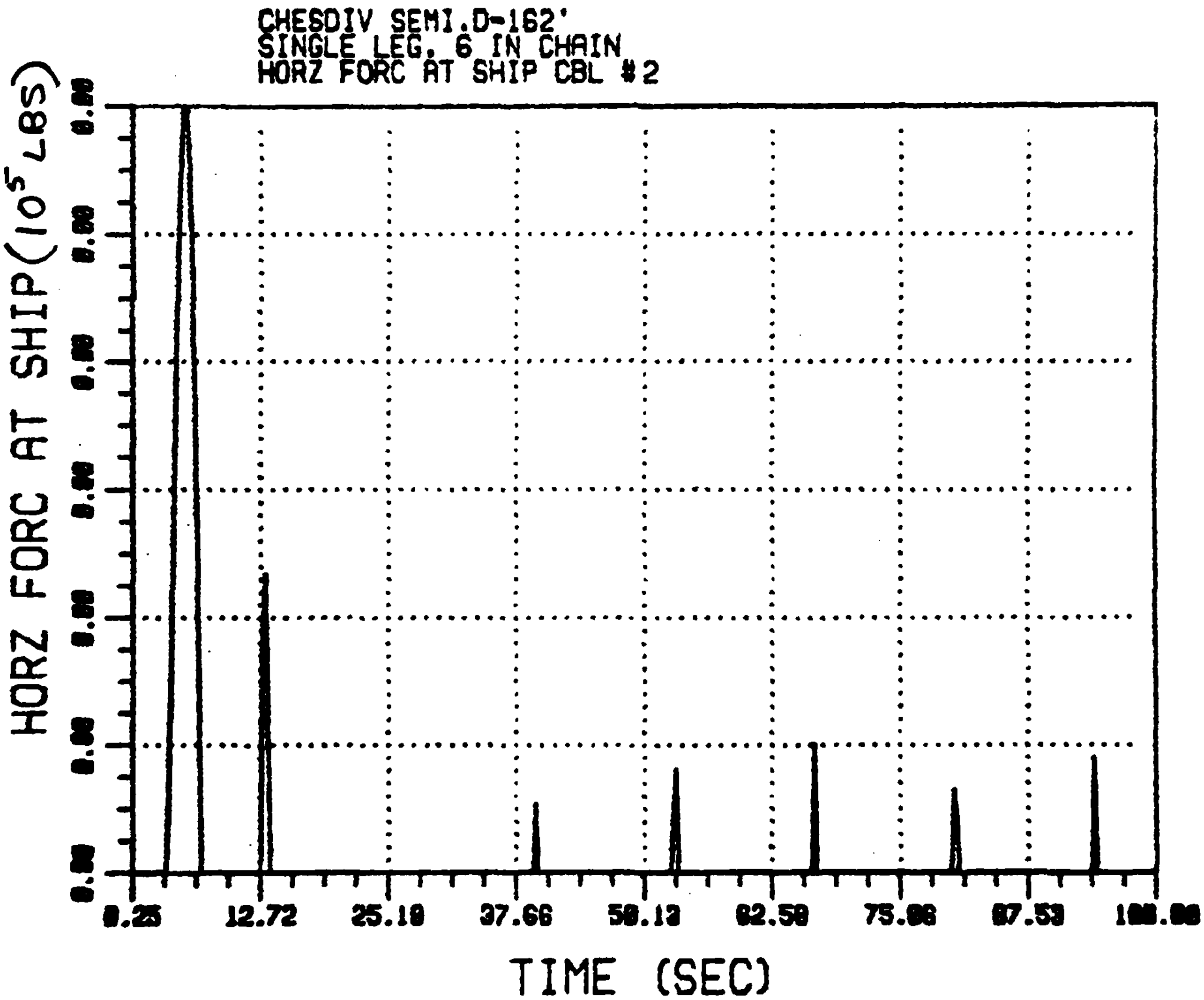
SINGLE LEGS.ALL CHAIN
6 IN CHAIN, SURVIVAL
TENS FORC AT SHIP CBL #1
TENS FORC AT SHIP (10^5 LBS)
2.01
12.72
25.18
37.66
75.88
87.53
TIME (SEC)

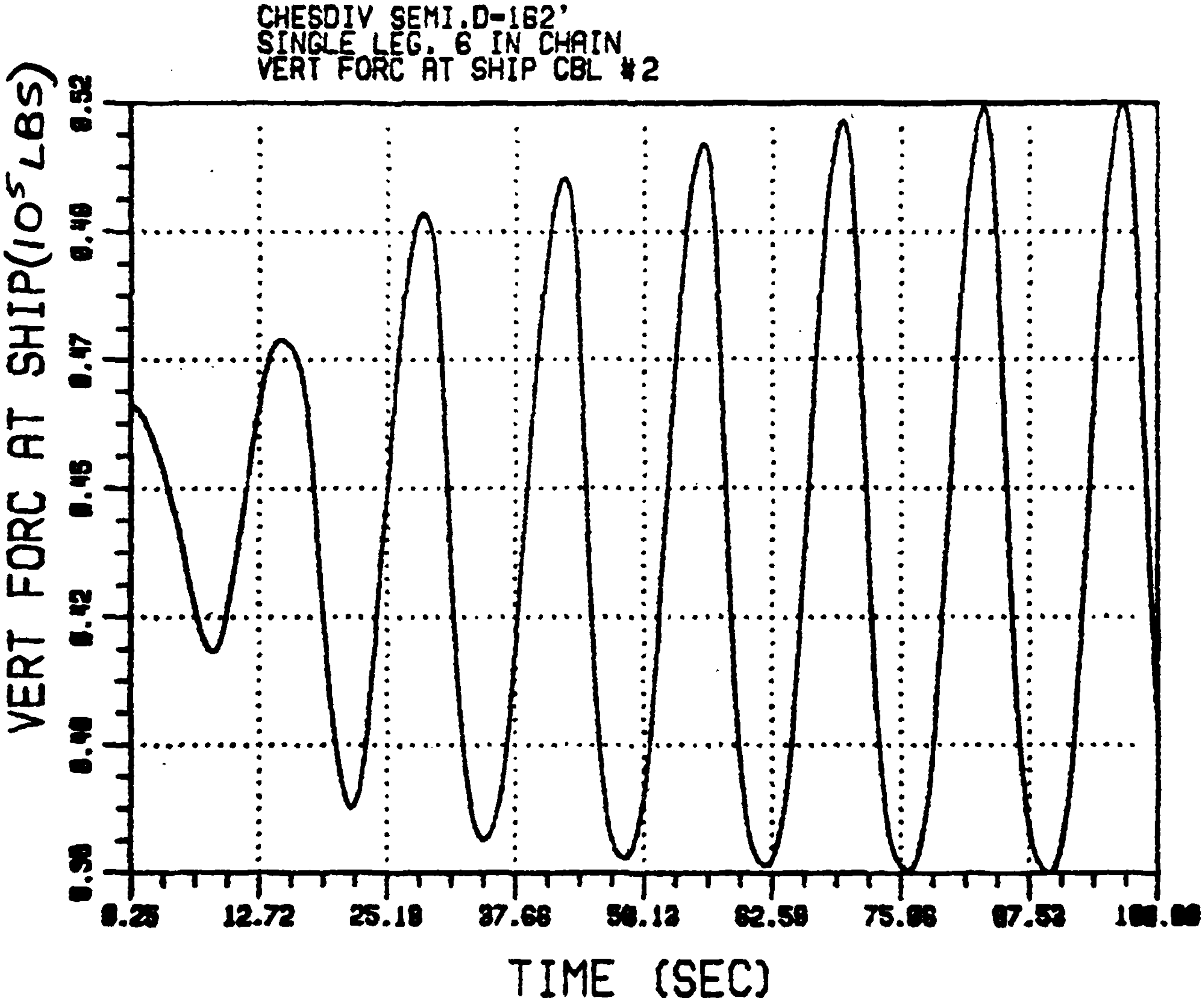


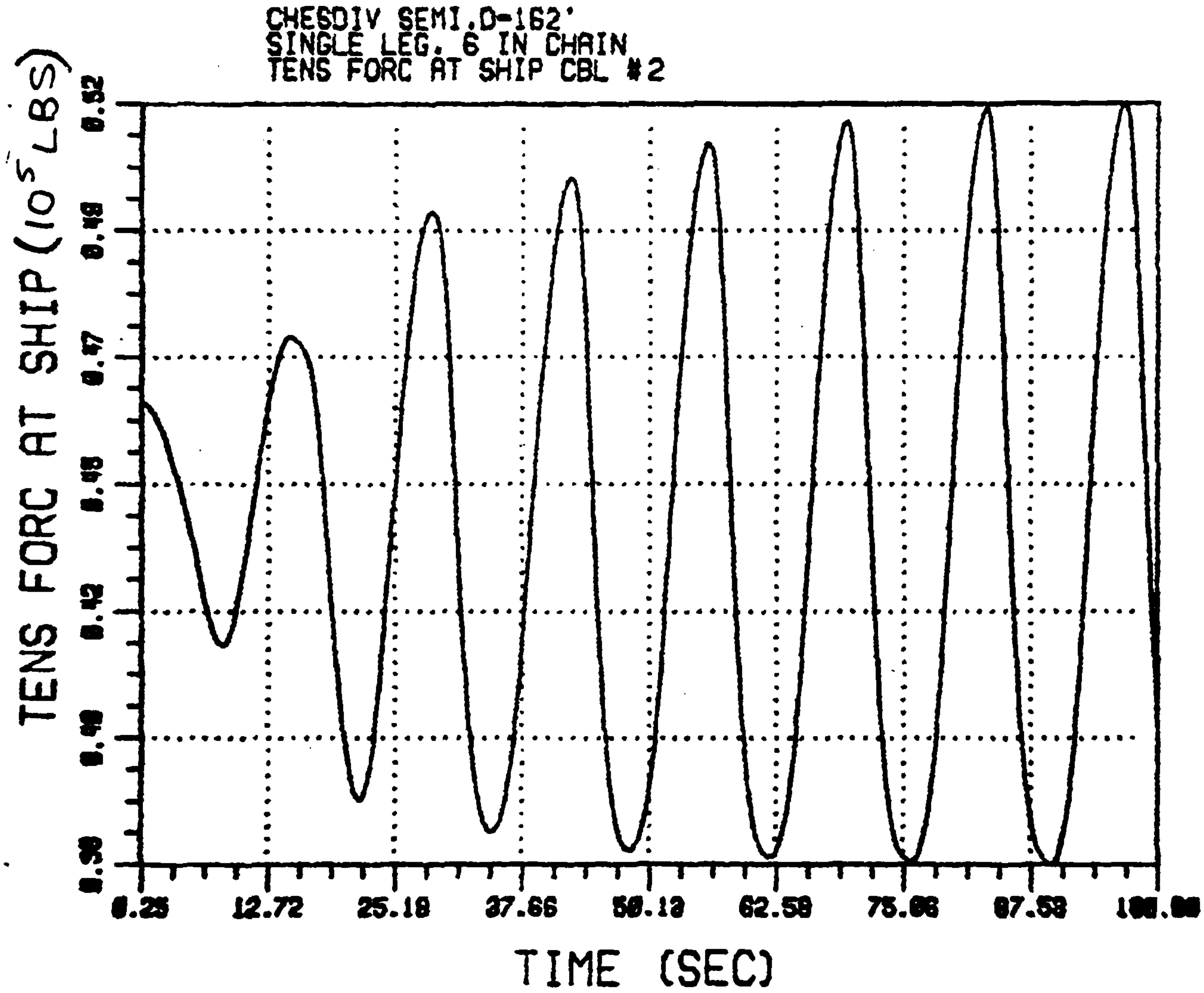
SINGLE LEGS.ALL CHAIN
6 IN CHAIN. SURVIVAL
HORZ FORC AT ANCH CBL #1
HORZ FORC AT ANCH (10^5 LBS)
2.17
12.72
25.10
TIME (SEC)

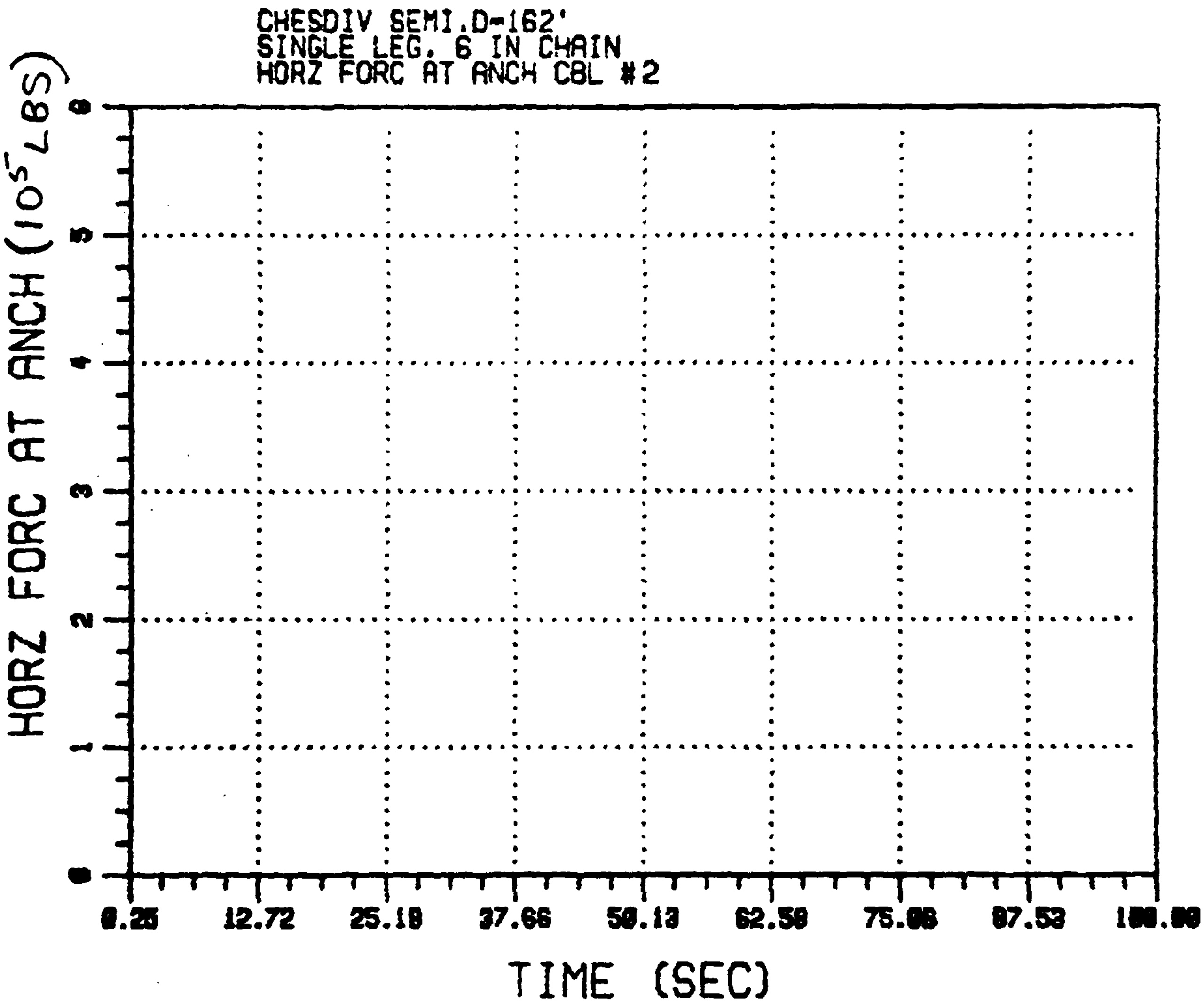


SINGLE LEGS.ALL CHAIN
6 IN CHAIN, SURVIVAL
VERT FORC AT ANCH CBL #1
VERT FORC AT ANCH (10^5 LBS)
12.72
25.18
TIME (SEC)

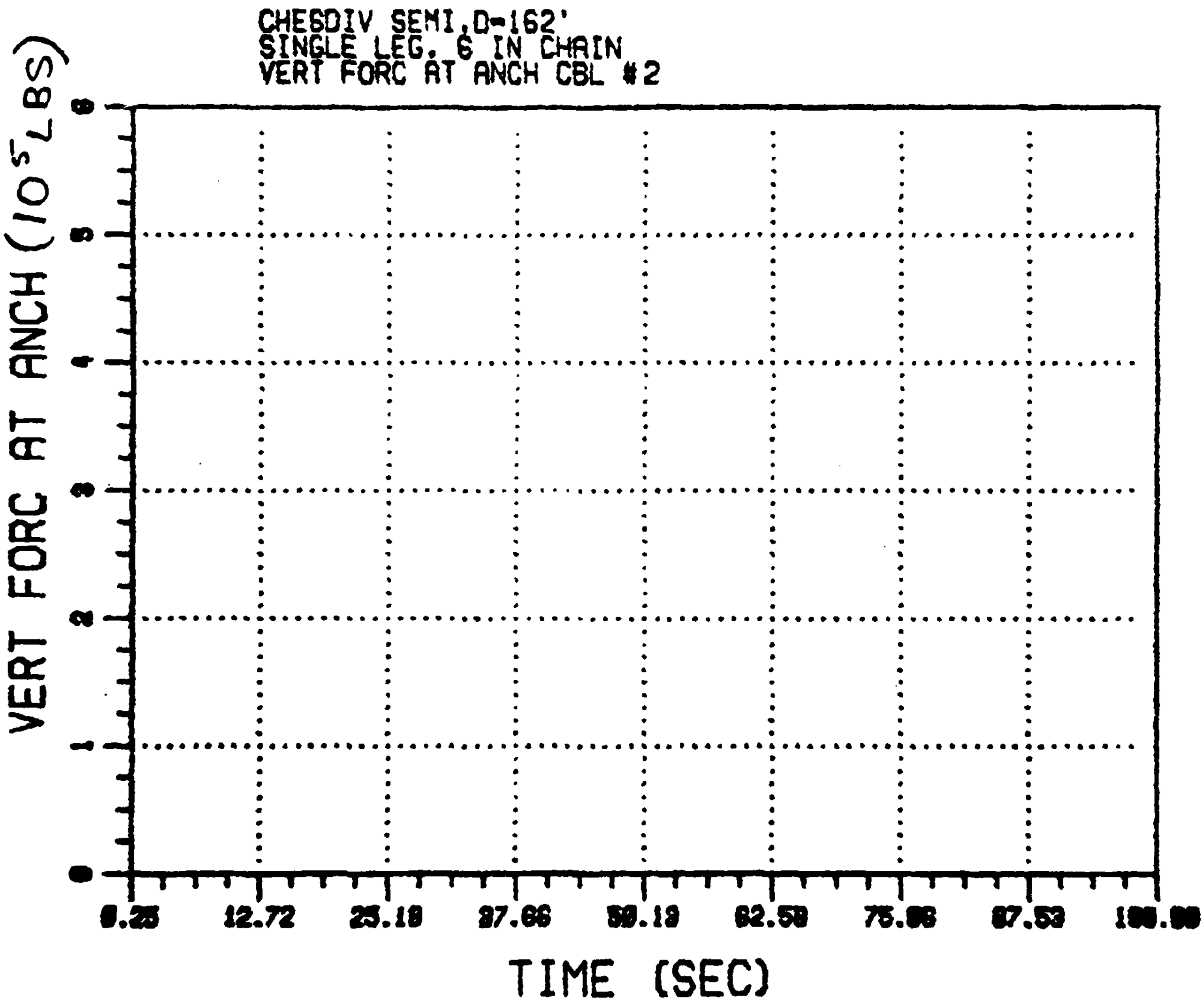

CHESDIV SEMI.D-162'
SINGLE LEG, 6 IN CHAIN
HORZ FORC AT SHIP CBL #2
HORZ FORC AT SHIP(10^5 LBS)
TIME (SEC)


CHESDIV SEMI.D-162'
SINGLE LEG. 6 IN CHAIN
VERT FORC AT SHIP CBL #2
VERT FORC AT SHIP(10^5 LBS)
12.72
25.18
TIME (SEC)


CHESDIV SEMI.D-162'
SINGLE LEG. 6 IN CHAIN
TENS FORC AT SHIP CBL #2
TENS FORC AT SHIP (10^5 LBS)
12.72
25.19
37.66
TIME (SEC)



CHESDIV SEMI.D-162'
SINGLE LEG. 6 IN CHAIN
HORZ FORC AT ANCH CBL #2
HORZ FORC AT ANCH (10^5 LBS)
0
1
2
3
4
5
6
0.25
12.72
25.19
37.66
50.13
62.59
75.06
87.53
100.00
TIME (SEC)


CHESDIV SEMI,D=162'
SINGLE LEG, 6 IN CHAIN
VERT FORC AT ANCH CBL #2
VERT FORC AT ANCH (10^5LBS)
TIME (SEC)

SUMMARY OF RESULTS

EFFECTIVE WATER DEPTH = 162 FT

DESIGN WAVE HEIGHT (FT) = 64.0
WAVE PERIOD (SEC) = 13.6
MAX CREST ELEVATION (FT) = 40.58
MIN TROUGH ELEVATION (FT) = −23.17
MEAN ELEVATION (FT) = +8.71

MAX/MIN SURGE OFFSET (FT) = 1.32/−125.9
MEAN SURGE OFFSET (FT) = −87.3
MAX 1st ORDER MOTIONS (FT) = ± 38.6

MAX/MIN HEAVE OFFSET (FT) = 18.69/−24.70
MEAN HEAVE OFFSET (FT) = −3.01
MAX 1st ORDER MOTION (FT) = ± 21.7

MAX/MIN PITCH ANGLE (DEG) = 18.3/−24.8
MEAN PITCH ANGLE (DEG) = −5.4
MAX 1st ORDER MOTION (DEG) = ± 19.4

MAX HORIZONTAL FORCE @ VESSEL (KIPS) = 939
MIN HORIZONTAL FORCE @ VESSEL (KIPS) = 0
MEAN HORIZONTAL FORCE @ VESSEL (KIPS) = 470

MAX VERTICAL FORCE @ VESSEL (KIPS) = 264
MIN VERTICAL FORCE @ VESSEL (KIPS) = 57
MEAN VERTICAL FORCE @ VESSEL (KIPS) = 160.5

MAX TENSION @ VESSEL (KIPS) = 974
MIN TENSION @ VESSEL (KIPS) = 50
MEAN TENSION @ VESSEL (KIPS) = 512

MAX HORZ. FORCE @ ANCHOR (KIPS) = 652
MIN HORZ. FORCE @ ANCHOR (KIPS) = 0

MAX VERTICAL FORCE @ ANCHOR (KIPS) = 0
MIN VERTICAL FORCE @ ANCHOR (KIPS) = 0

CHAIN DIAMETER (IN) = 6.0
LENGTH OF CHAIN (FT) = 3,000
LOCATION OF ANCHOR (FT) = 2,850
PROOF LOAD (KIPS) = 2,280

(PEAK TENSION / PROOF LOAD) × 100 = 42.7 %

TABLE-3.5 SUMMARY RESULTS – DEPTH 162 FT

APPENDIX A.4

WATER DEPTH	=	100 FT
EFFECTIVE DEPTH	=	112 FT
WAVE HEIGHT	=	61 FT
WAVE PERIOD	=	13.6 SEC
CURRENT	=	3 KN
WIND	=	150 KN
MOORING CHAIN	=	6 IN

ITEM	WEIGHT (S. TONS)
SEMISUBMERSIBLE + PAYLOAD	65.1
MOORING SYSTEM VERTICAL COMPONENT	66.4
BALLAST	120.0
TOTAL DISPLACEMENT	251.5

SEMISUBMERSIBLE WEIGHT DISTRIBUTION

DEPTH = 112 FT

**** CALCULATED DISPLACEMENT PROPERTIES ****

DISPLACEMENT	=	0.49987E 06
CENTER OF BUOYANCY ALONG X-AXIS	=	0.00
CENTER OF BUOYANCY ALONG Y-AXIS	=	0.00
CENTER OF BUOYANCY ALONG Z-AXIS	=	-19.89

**** STRUCTURAL INPUT PROPERTIES ****

FREQUENCY DOMAIN RESULTS

UNITS : LBS, FEET

STRUCTURAL WEIGHT	=	0.37040E 06
ROLL RADIUS OF GYRATION	=	24.50
PITCH RADIUS OF GRYRATION	=	24.50
YAW RADIUS OF GRYRATION	=	30.30
CENTER OF GRAVITY ALONG X-AXIS	=	0.00
CENTER OF GRAVITY ALONG Y-AXIS	=	0.00
CENTER OF GRAVITY ALONG Z-AXIS	=	-18.40

**** WATER INPUT PROPERTIES ****

MASS DENSITY OF WATER	=	1.99
ACCELERATION OF GRAVITY	=	32.17
WAVE HEIGHT	=	61.00
WAVE PERIOD	=	13.60
WATER DEPTH	=	112.00
ANGLE OF ATTACK IN DEGREES	=	180.00

**** CALCULATED WATERPLANE PROPERTIES ****

WATERPLANE AREA	=	94.51
CENTER OF AREA ALONG X-AXIS	=	0.00
CENTER OF AREA ALONG Y-AXIS	=	-0.00
WATERPLANE INERTIA ABOUT X-AXIS	=	0.66787E 05
WATERPLANE INERTIA ABOUT Y-AXIS	=	0.66783E 05
METACENTRIC HEIGHT IN ROLL	=	7.07
METACENTRIC HEIGHT IN PITCH	=	7.07

**** CENTERS ARE IN ORIGINAL SYSTEM ****

**** INERTIAS ARE ABOUT AXES THRU CG ***

BODY MASS MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.11512401E 05	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00
SWAY	0.00000000E 00	0.11512401E 05	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00
HEAVE	0.00000000E 00	0.00000000E 00	0.11512401E 05	0.00000000E 00	0.00000000E 00	0.00000000E 00
ROLL	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.69103189E 07	0.00000000E 00	0.00000000E 00
PITCH	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.69103189E 07	0.00000000E 00
YAW	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.10569421E 08

ADDED MASS MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.96193757E 04	-0.20929747E-09	-0.64801498E-11	-0.13715180E-08	0.39628513E 04	0.24875936E-01
SWAY	-0.20929747E-09	0.96179669E 04	-0.34106051E-11	-0.39708223E 04	-0.10168151E-08	0.22230983E 02
HEAVE	-0.64801498E-11	-0.34106051E-11	0.12226625E 05	0.24875950E-01	-0.31666512E 02	-0.13096724E-09
ROLL	-0.13715180E-08	-0.39708223E 04	0.24875950E-01	0.47664615E 07	-0.69180542E 00	-0.67668031E 02
PITCH	0.39628513E 04	-0.10168151E-08	-0.31666512E 02	-0.69180544E 00	0.47657661E 07	-0.14137762E 00
YAW	0.24875936E-01	0.22230983E 02	-0.13096724E-09	-0.67668031E 02	-0.14137763E 00	0.93184866E 07

HYDROSTATIC STIFFNESS MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00
SWAY	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00
HEAVE	0.00000000E 00	0.00000000E 00	0.60525515E 04	-0.46596940E-09	-0.20175172E 02	0.00000000E 00
ROLL	0.00000000E 00	0.00000000E 00	-0.46596940E-09	0.35321439E 07	-0.15532313E-11	0.00000000E 00
PITCH	0.00000000E 00	0.00000000E 00	-0.20175172E 02	-0.15532313E-11	0.35318939E 07	0.00000000E 00
YAW	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00	0.00000000E 00

MOORING STIFFNESS MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.18659776E 04	-0.18189894E-11	-0.39273013E 02	-0.40745363E-09	0.50758620E 05	0.60936145E-10
SWAY	-0.18189894E-11	0.18803688E 04	-0.18189894E-11	-0.50890454E 05	-0.64028427E-09	-0.51525146E 02
HEAVE	-0.39273013E 02	-0.18189894E-11	0.24362484E 04	-0.12805685E-08	-0.22095016E 02	0.61071148E-10
ROLL	-0.40745363E-09	-0.50890454E 05	-0.12805685E-08	0.23328531E 07	-0.35390258E-07	-0.20162044E 03
PITCH	0.50758620E 05	-0.64028427E-09	-0.22095016E 02	-0.35390258E-07	0.23325967E 07	0.13387762E-07
YAW	0.60936145E-10	-0.51525146E 02	0.61071148E-10	-0.20162044E 03	0.13387762E-07	0.33600680E 05

MODE SHAPE MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.99993553E 00	-0.36602174E-06	-0.33797773E-02	0.18694248E-03	0.98290025E 00	0.31395447E-07
SWAY	0.36194477E-06	0.99995079E 00	-0.36383510E-07	-0.98268945E 00	0.18834181E-03	0.37998882E-01
HEAVE	0.55903296E-02	0.26823089E-09	0.99998551E 00	-0.26929043E-05	-0.10956070E-01	0.14615891E-09
ROLL	0.36747540E-08	0.99204957E-02	0.41742984E-08	0.18526036E 00	-0.35493861E-04	0.36522143E-03
PITCH	-0.98835171E-02	0.35345754E-08	0.17546755E-03	0.35391457E-04	0.18593864E 00	-0.31310830E-09
YAW	-0.13982809E-08	-0.43031771E-04	0.81331997E-11	0.29817408E-05	-0.47952081E-09	0.99927771E 00

NATURAL PERIOD IN SURGE= 0.24707542E 02
NATURAL PERIOD IN SWAY = 0.24603667E 02
NATURAL PERIOD IN HEAVE= 0.10507101E 02
NATURAL PERIOD IN ROLL = 0.86761619E 01
NATURAL PERIOD IN PITCH= 0.86774413E 01
NATURAL PERIOD IN YAW = 0.15363364E 03

PERIOD	LENGTH	SURGE	PHASE	SWAY	PHASE	HEAVE	PHASE	ROLL	PHASE	PITCH	PHASE	YAW	PHASE
13.60	714.98	1.2142	72.50	0.0000	-25.71	0.6635	-152.50	0.00000	137.57	0.76883	-158.32	0.00000	-50.92

WAVE PERIOD= 13.60

	INERTIAL FORCES		FROUDE-KRYLOV FORCES		VISCOUS DRAG FORCES	
	AMPLITUDE	PHASE SHIFT	AMPLITUDE	PHASE SHIFT	AMPLITUDE	PHASE SHIFT
SURGE	0.72479771E 05	0.92161353E 02	0.11389908E 06	0.90145392E 02	0.38007571E 06	-0.17720427E 03
SWAY	0.12153173E-02	-0.11556863E 02	0.13503446E-02	-0.11557096E 02	0.60406666E-02	0.75931545E 02
HEAVE	0.58734569E 05	-0.17999813E 03	0.11731640E 06	0.11329884E 00	0.31804846E 06	-0.87936554E 02
ROLL	0.11297035E 00	0.16585334E 03	0.12552277E 00	0.16585331E 03	0.20828209E 00	-0.10784911E 03
PITCH	0.12021522E 06	-0.85423975E 02	0.71085235E 06	0.83881615E 02	0.10817936E 07	-0.81052236E 02
YAW	0.18388933E 00	0.74040419E 02	0.20432128E 00	0.74040520E 02	0.78409388E 00	0.15932872E 03

DAMPING MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.23275247E 05	-0.21728792E-04	-0.79976926E 02	0.29314123E-03	0.35628622E 05	0.48481858E-01
SWAY	-0.21728792E-04	0.19473069E 05	-0.26484267E-04	-0.55742934E 05	0.42969012E-04	-0.14343489E 04
HEAVE	-0.79976926E 02	-0.26484267E-04	0.29951629E 05	0.22812949E-01	0.11119204E 06	-0.33611551E-03
ROLL	0.29314123E-03	-0.55742934E 05	0.22812949E-01	0.12624822E 08	-0.71832015E 00	0.12695448E 06
PITCH	0.35628622E 05	0.42969012E-04	0.11119204E 06	-0.71832015E 00	0.11359907E 08	-0.33305576E 00
YAW	0.48481858E-01	-0.14343489E 04	-0.33611551E-03	0.12695448E 06	-0.33305577E 00	0.20355338E 08

CATENARY MATRIX

	SURGE	SWAY	HEAVE	ROLL	PITCH	YAW
SURGE	0.65188889E 04	-0.90949470E-12	-0.45244110E 03	-0.17462298E-09	0.79478433E 05	-0.24556357E-10
SWAY	-0.90949470E-12	0.16331483E 04	-0.18189894E-11	-0.48627850E 05	-0.58207661E-10	0.50723253E 01
HEAVE	-0.45244110E 03	-0.18189894E-11	0.24361130E 04	-0.29103830E-09	-0.89852468E 02	0.46021853E-10
ROLL	-0.17462298E-09	-0.48627850E 05	-0.29103830E-09	0.23291140E 07	-0.11175871E-07	-0.19182868E 03
PITCH	0.79478433E 05	-0.58207661E-10	-0.89852468E 02	-0.11175871E-07	0.23473946E 07	0.56570570E-09
YAW	-0.24556357E-10	0.50723253E 01	0.46021853E-10	-0.19182868E 03	0.56570570E-09	0.33591484E 05

MOORING SYSTEM USED : 6" GRADE 2 CHAIN

LENGTH = 2,000 FT

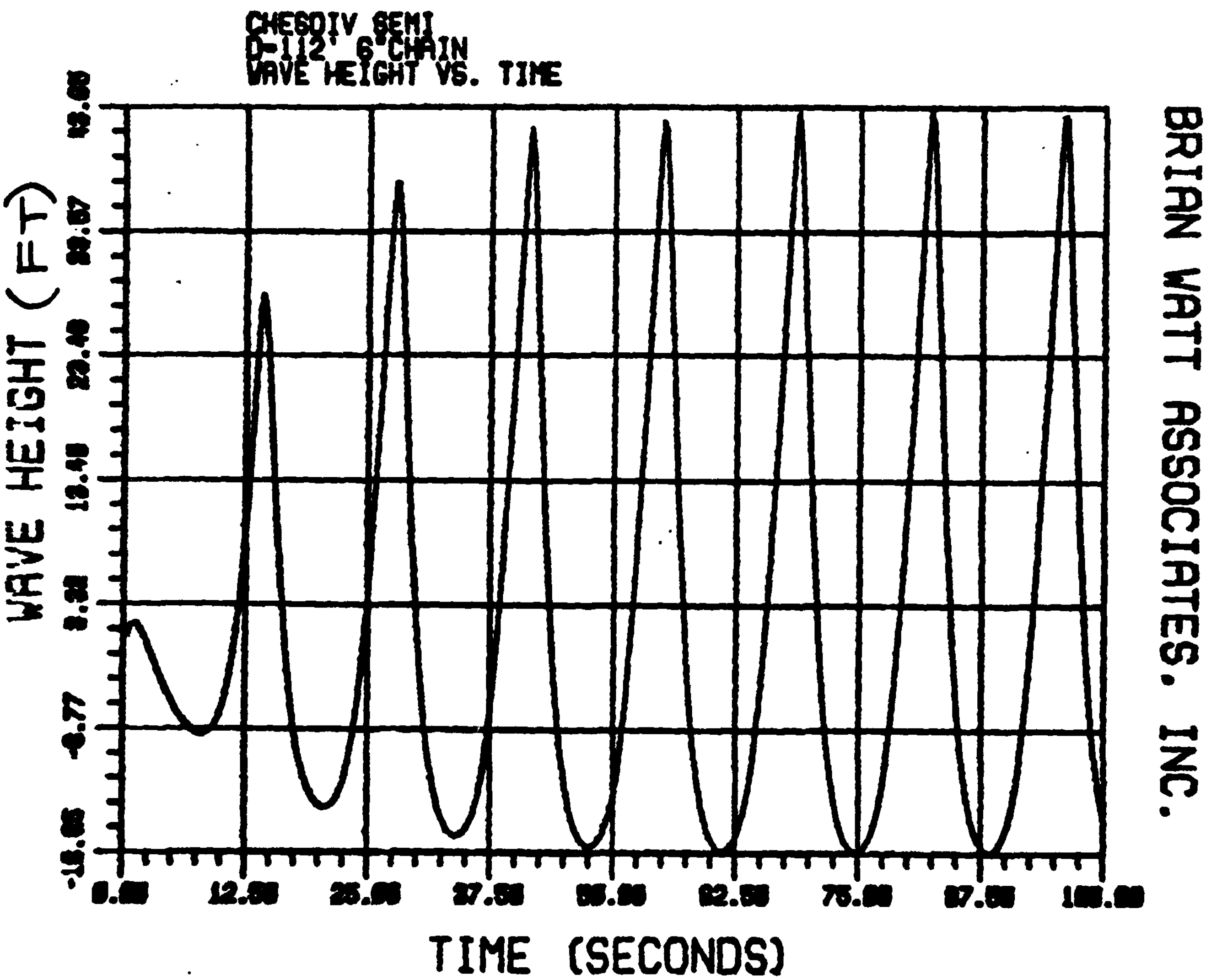
LOCATION OF ANCHOR = 1,950 FT

FORCES IN CATENARY LINES

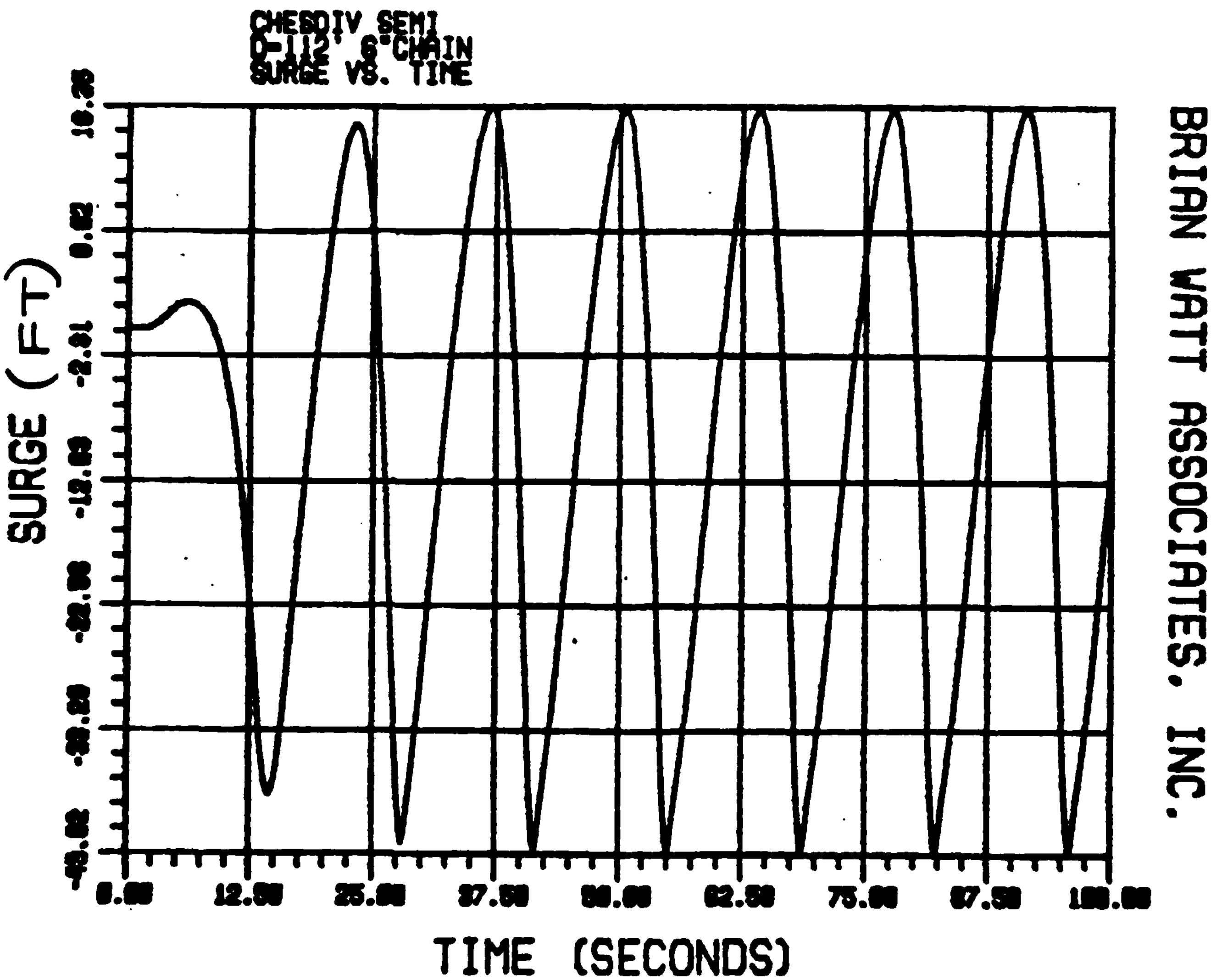
PERIOD	ELEMENT	MIN HOR FOR AT SHP MAX HOR FOR AT SHP	MIN VER FOR AT SHP MAX VER FOR AT SHP	MIN TEN AT SHP MAX TEN AT SHP	MIN HOR FOR AT BOT MAX HOR FOR AT BOT	MIN VER FOR AT BOT MAX VER FOR AT BOT
13.60	1	0.10422028E 05	0.38274347E 05	0.39667926E 05	0.00000000E 00	0.00000000E 00
		0.51741345E 06	0.17927428E 06	0.54759104E 06	0.20081168E 06	0.00000000E 00
13.60	2	0.15075322E 04	0.23682791E 05	0.23767716E 05	0.00000000E 00	0.00000000E 00
		0.18020977E 05	0.52256706E 05	0.54949548E 05	0.00000000E 00	0.00000000E 00
13.60	3	0.15075329E 04	0.23682792E 05	0.23767717E 05	0.00000000E 00	0.00000000E 00
		0.18020972E 05	0.52256703E 05	0.54949544E 05	0.00000000E 00	0.00000000E 00

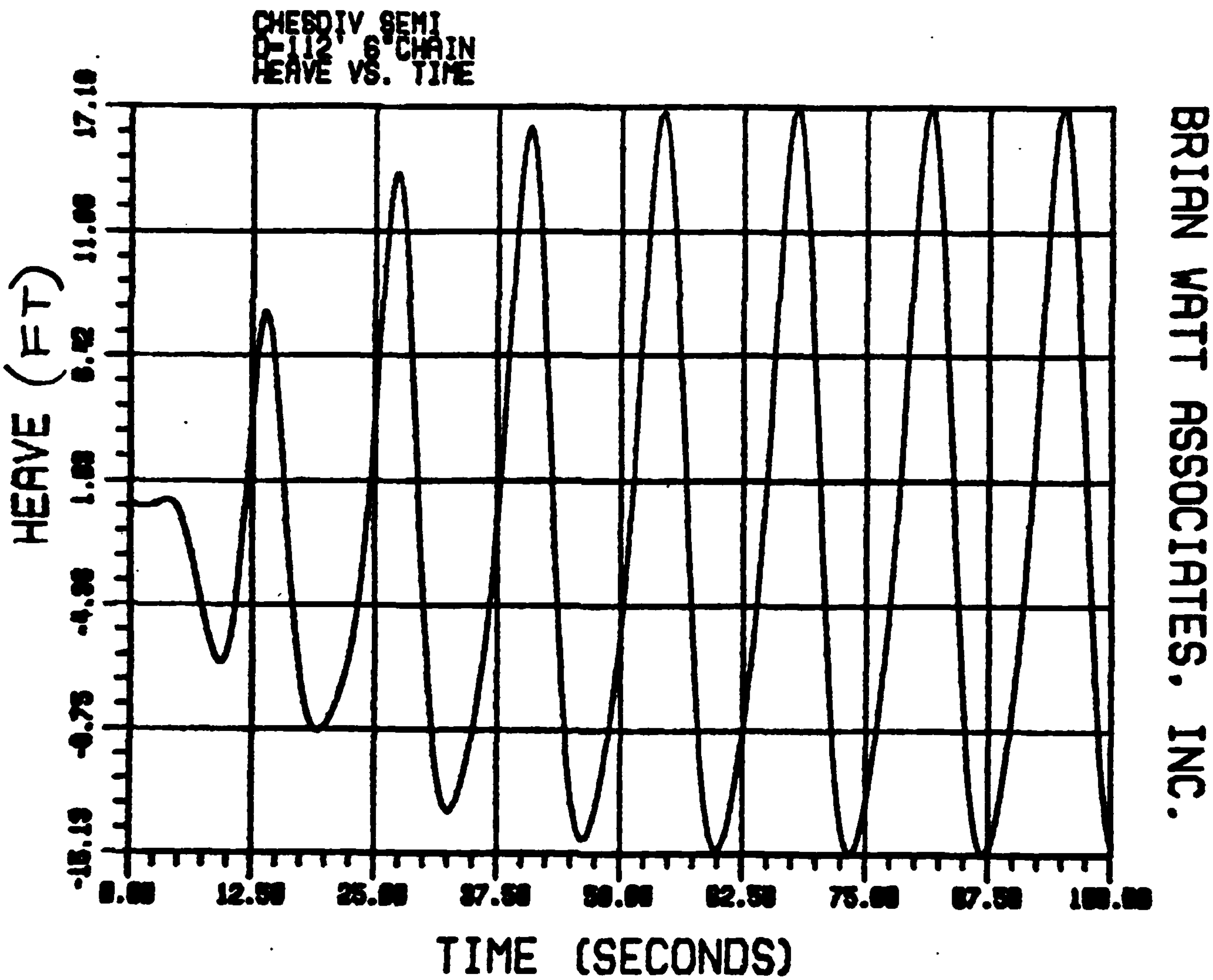
FORCES AT ANCHOR

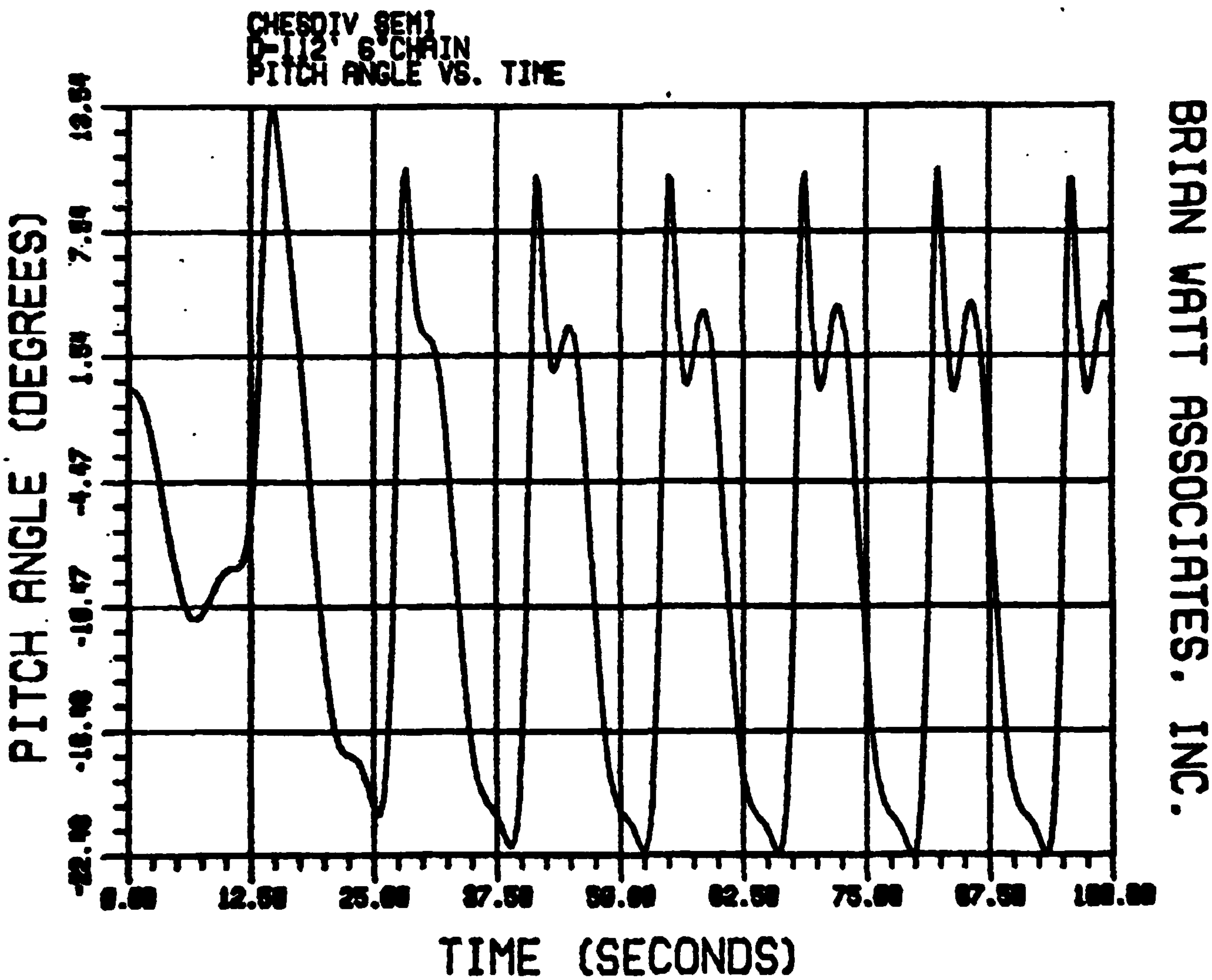
FORCES IN LBS.



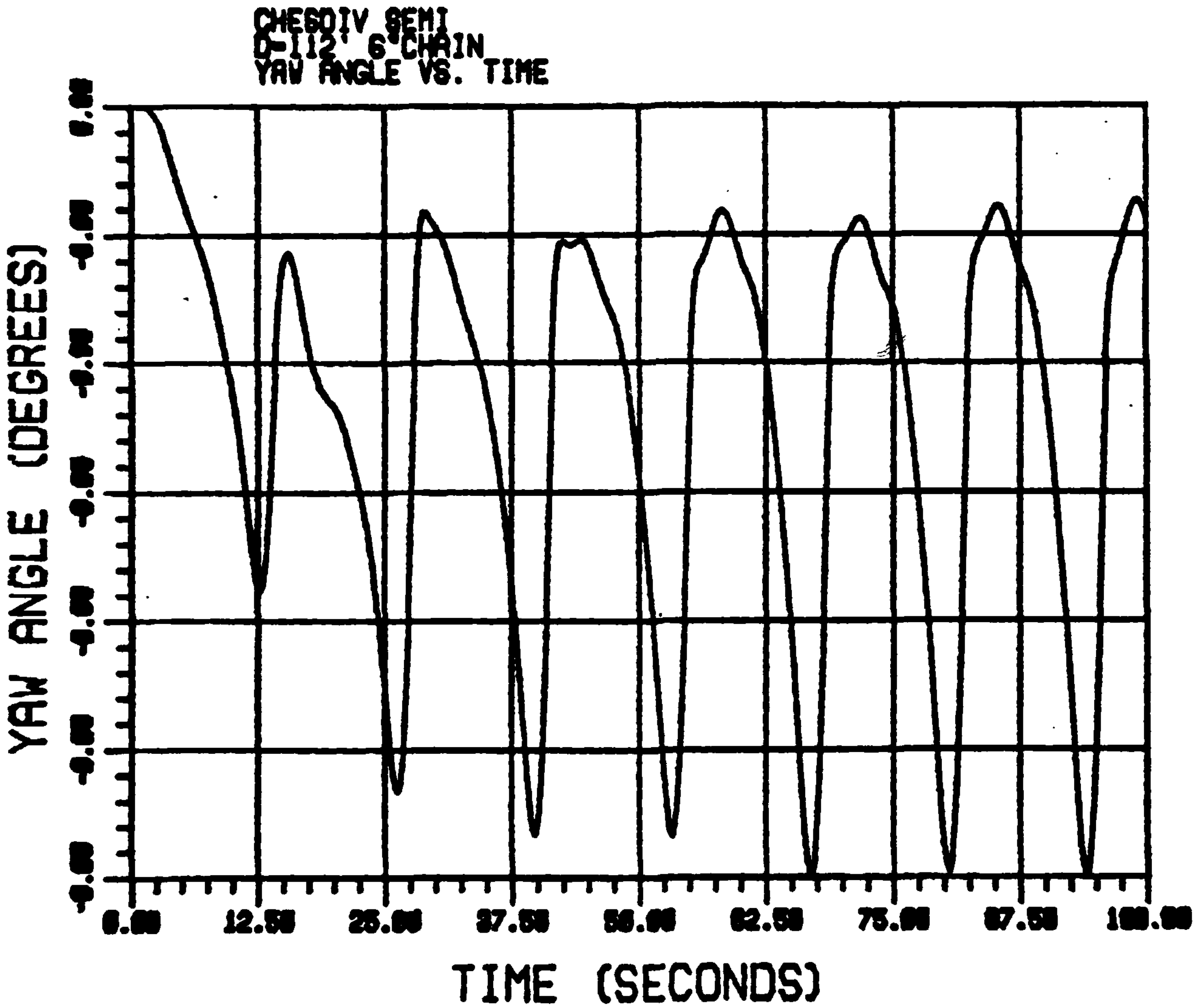
CHESDIV SEMI
D=112' 6"CHAIN
WAVE HEIGHT VS. TIME
WAVE HEIGHT (FT)
-6.77
12.50
TIME (SECONDS)
BRIAN WATT ASSOCIATES, INC.


CHESDIV SEMI
D-112' 6"CHAIN
SURGE VS. TIME
SURGE (FT)
TIME (SECONDS)
0.00
12.50
25.00
37.50
50.00
62.50
75.00
87.50
100.00
BRIAN WATT ASSOCIATES, INC.

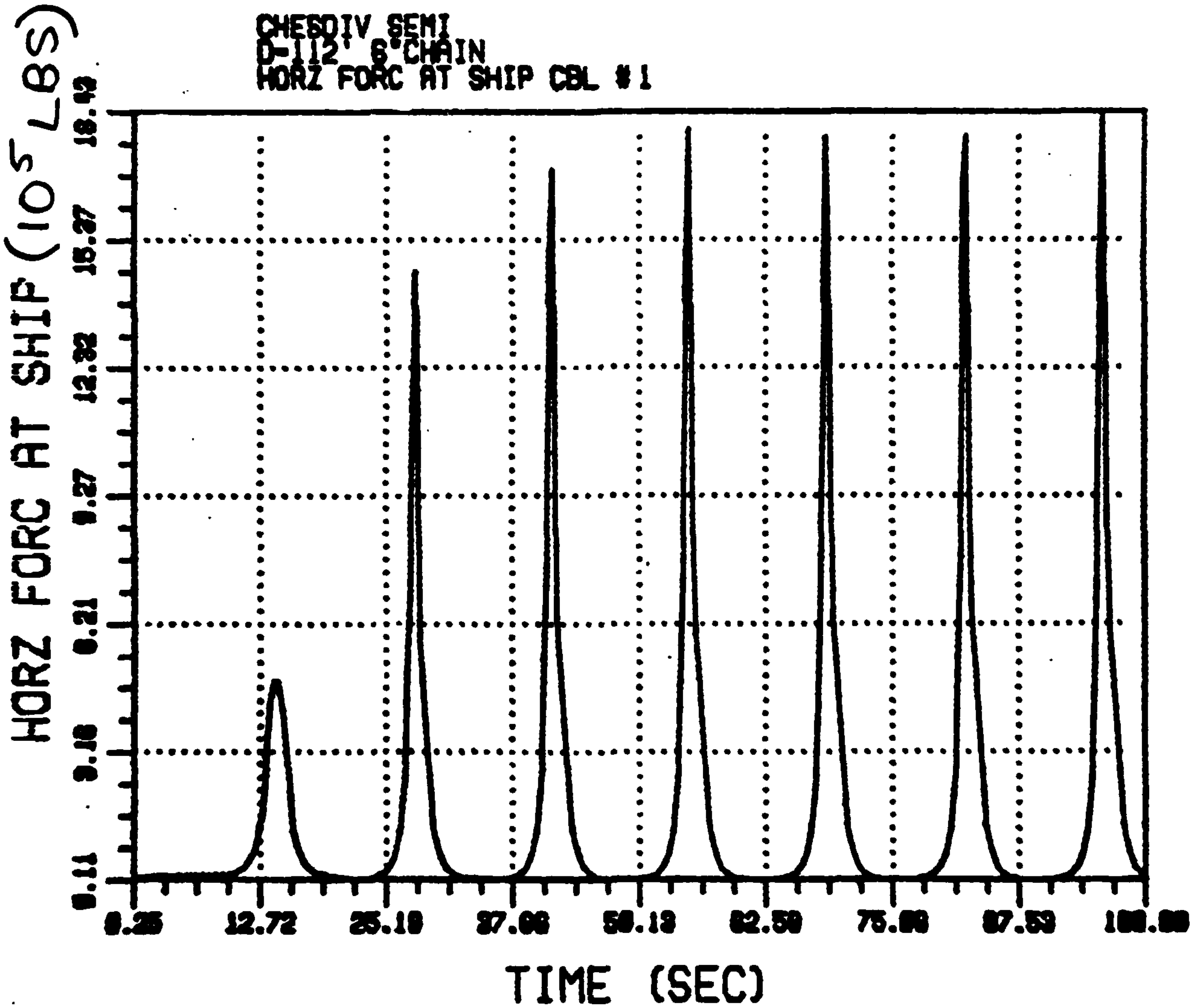

CHESDIV SEMI
D-112' 6"CHAIN
HEAVE VS. TIME
HEAVE (FT)
17.10
0.00
12.50
25.00
37.50
50.00
62.50
75.00
87.50
100.00
TIME (SECONDS)
BRIAN WATT ASSOCIATES, INC.

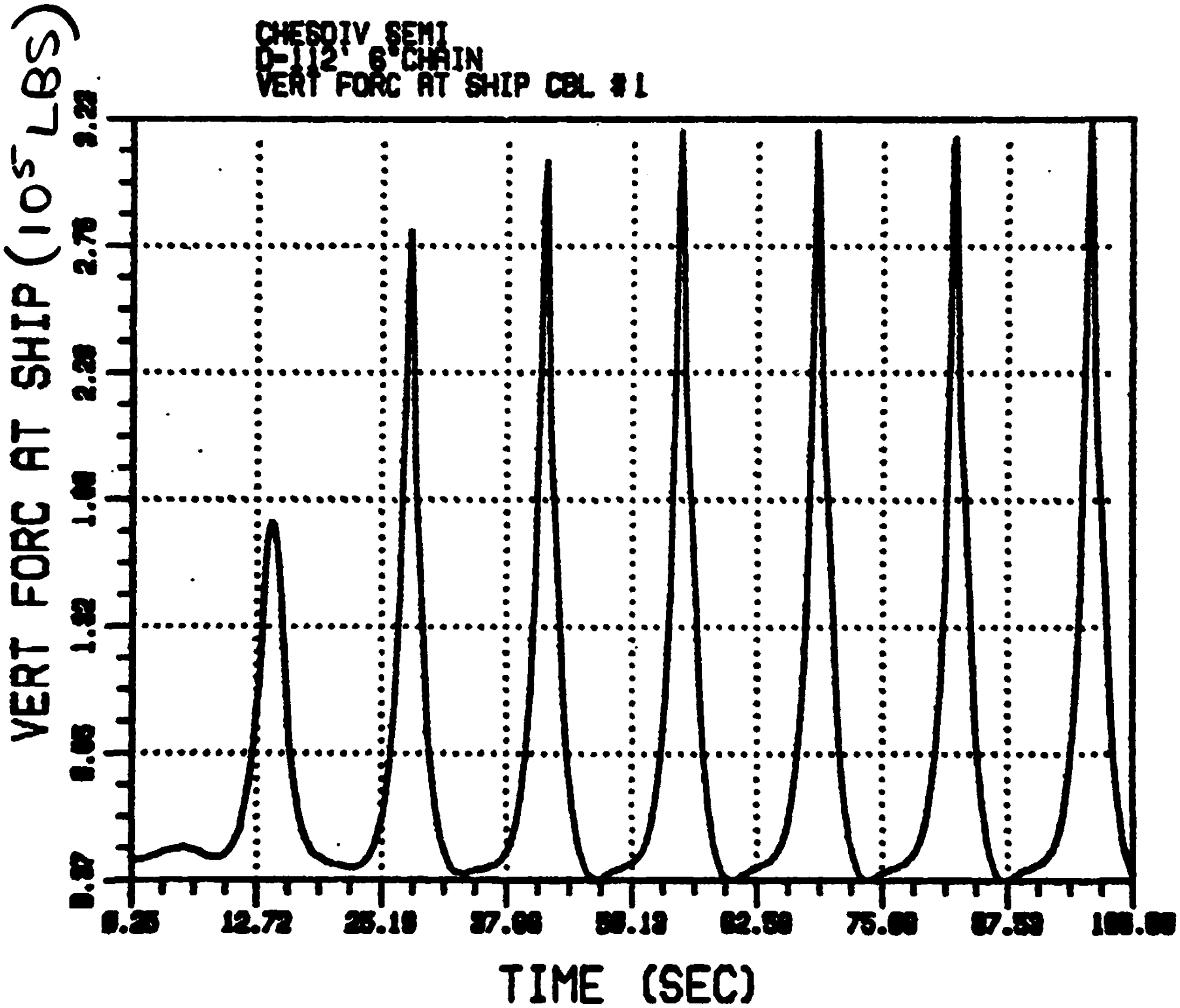


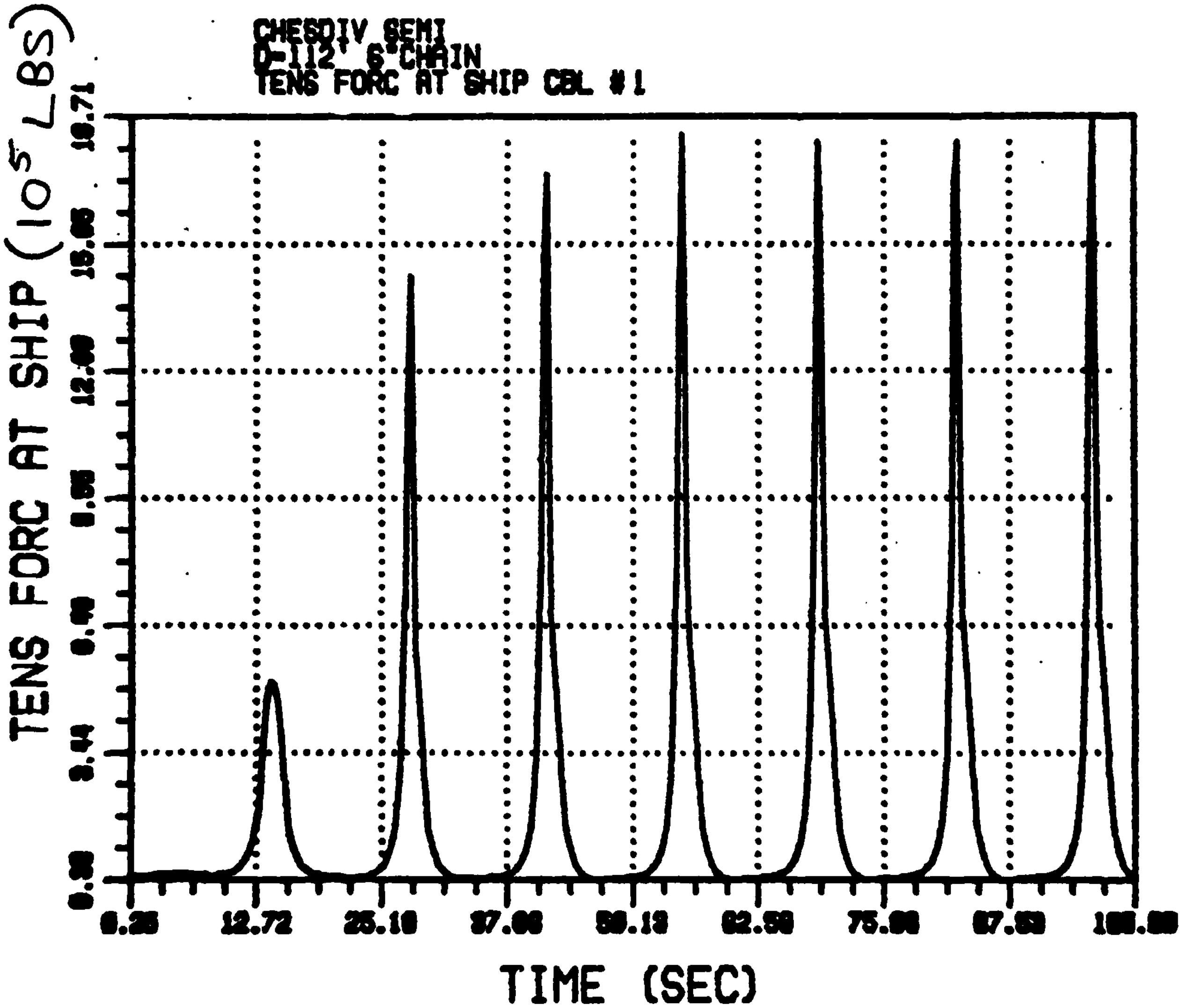
CHESDIV SEMI
D-112' 6"CHAIN
PITCH ANGLE VS. TIME
PITCH ANGLE (DEGREES)
TIME (SECONDS)
12.50
25.00
37.50
50.00
62.50
75.00
87.50
100.00
BRIAN WATT ASSOCIATES, INC.



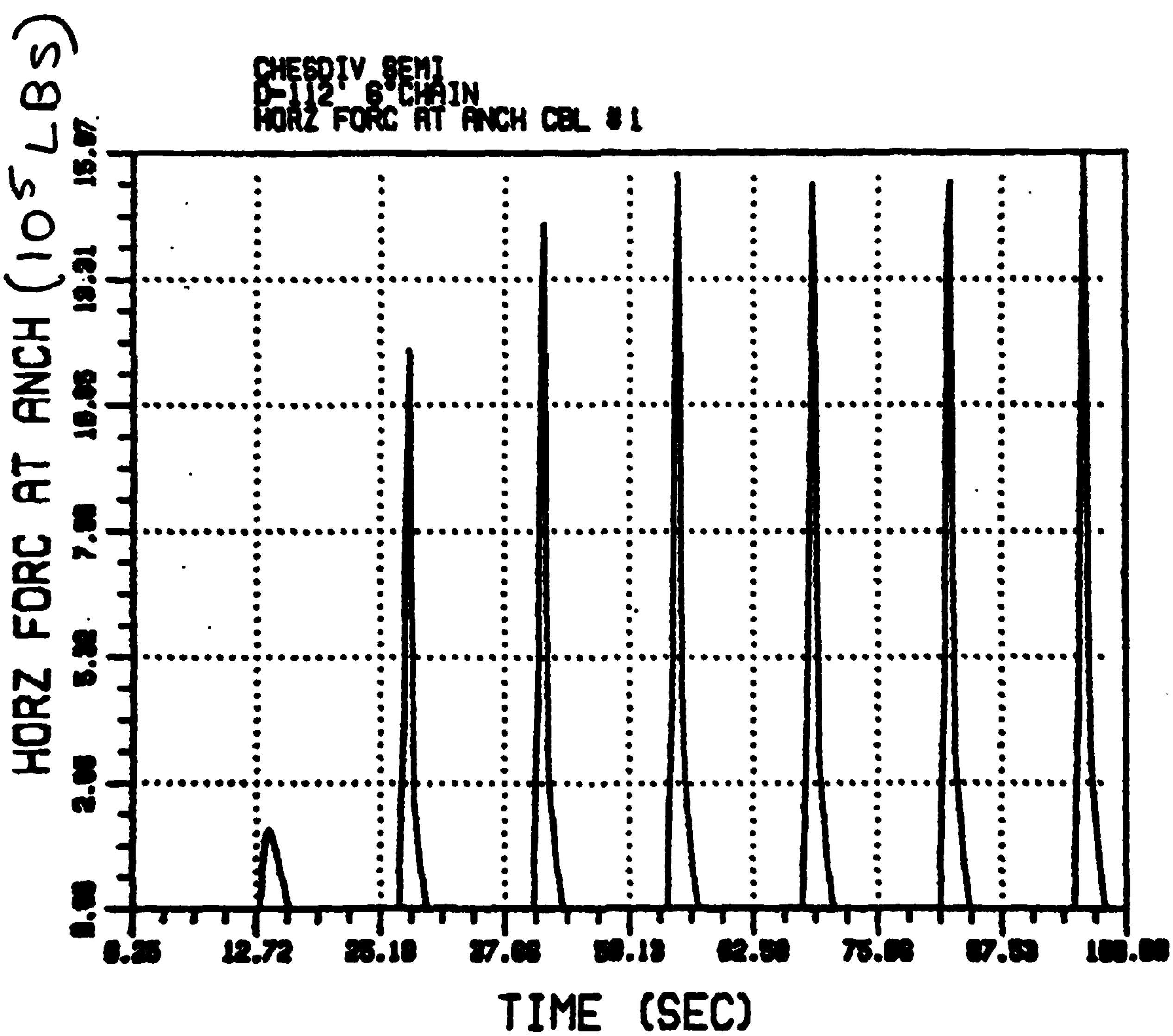
BRIAN WATT ASSOCIATES, INC.


CHESDIV SEMI
D-112' 6"CHAIN
HORZ FORC AT SHIP CBL #1
HORZ FORC AT SHIP (10^5 LBS)
TIME (SEC)

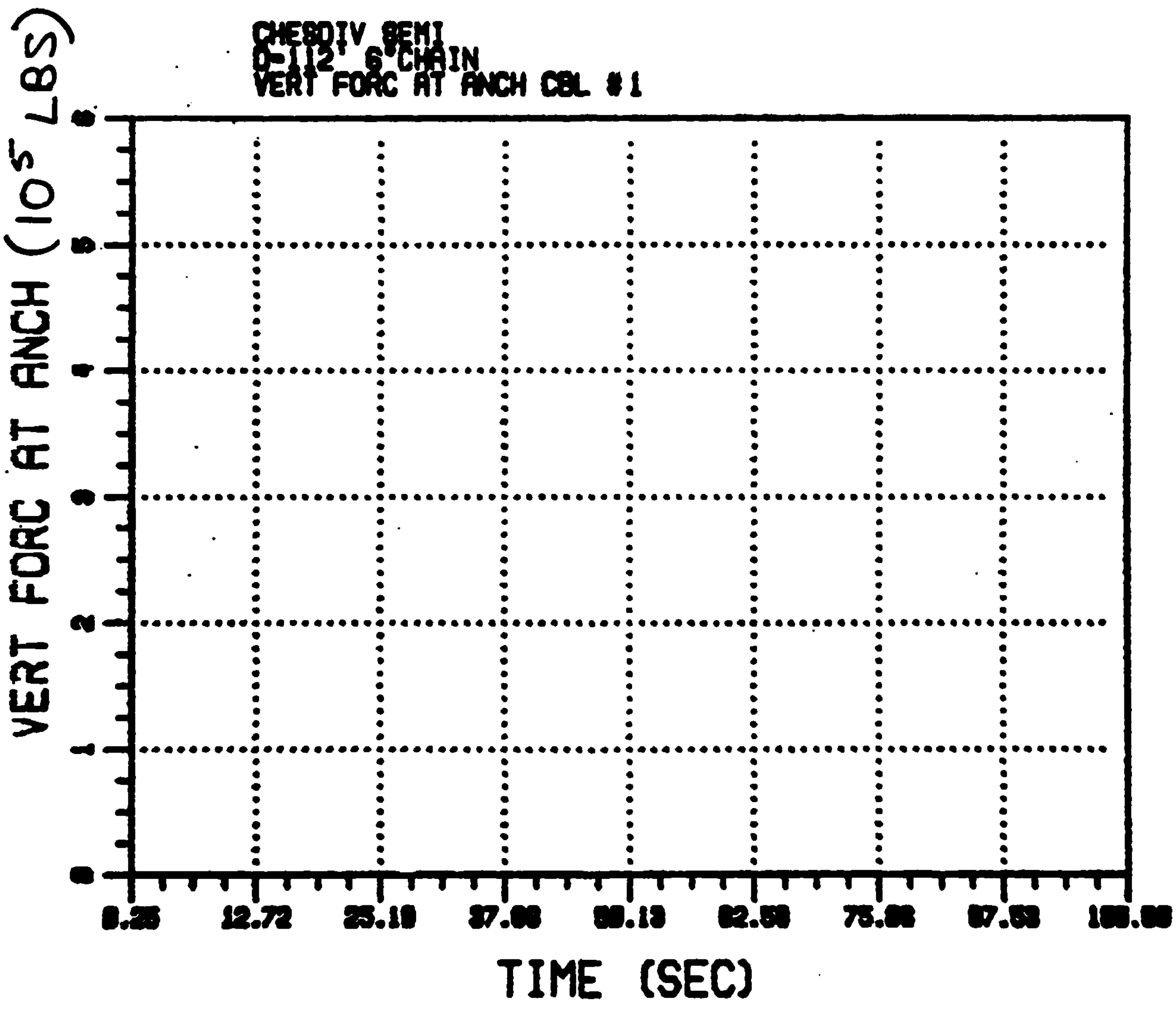

CHESDIV SEMI
D-112' 6"CHAIN
VERT FORC AT SHIP CBL #1
VERT FORC AT SHIP (10^5 LBS)
TIME (SEC)



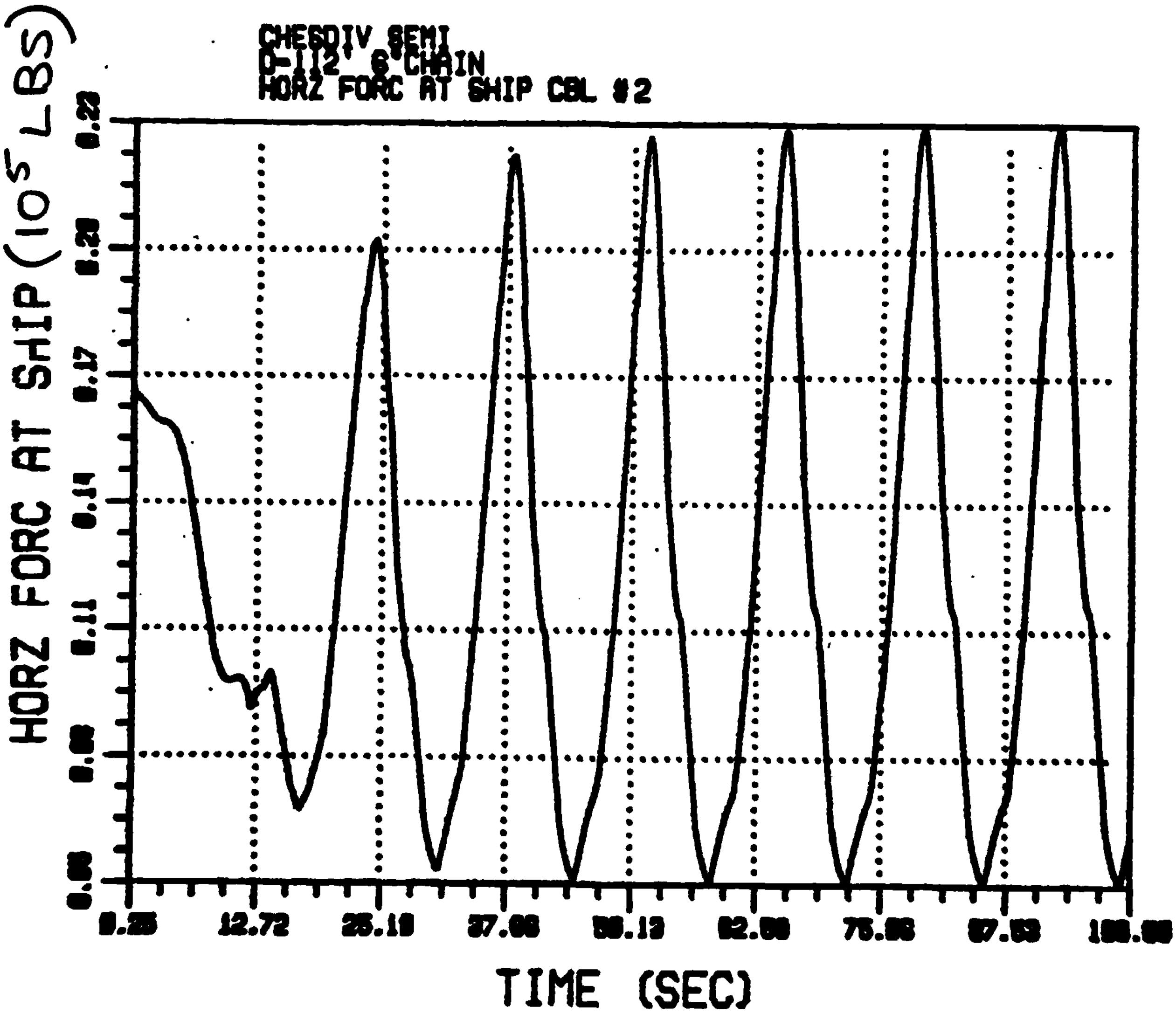
CHESDIV SEMI
TENS FORC AT SHIP CBL #1
TENS FORC AT SHIP (10^5 LBS)
18.71
3.44
12.72
25.18
TIME (SEC)



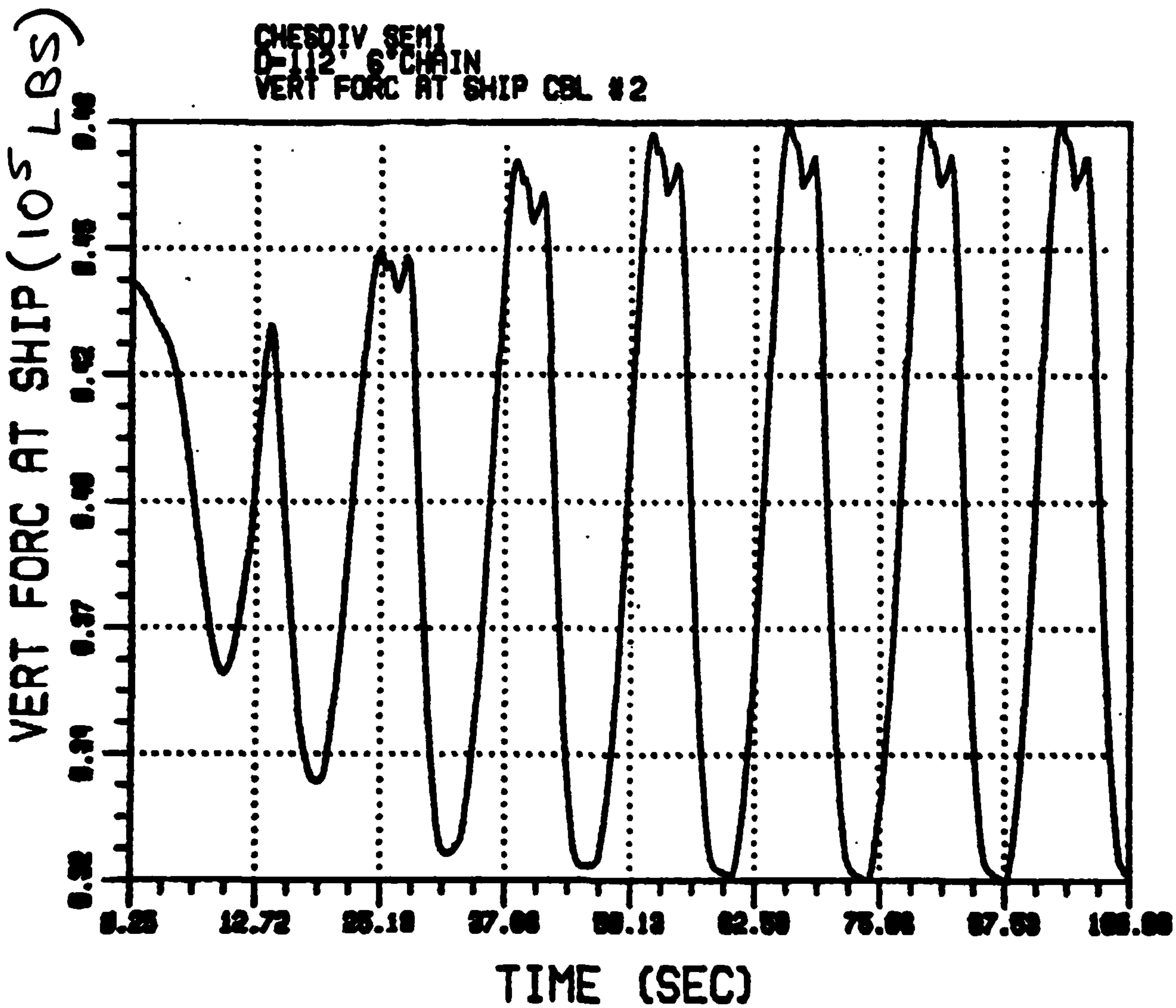
CHESDIV SEMI
D-112' 6"CHAIN
HORZ FORC AT ANCH CBL #1
HORZ FORC AT ANCH (10^5 LBS)
15.97
13.31
12.72
TIME (SEC)



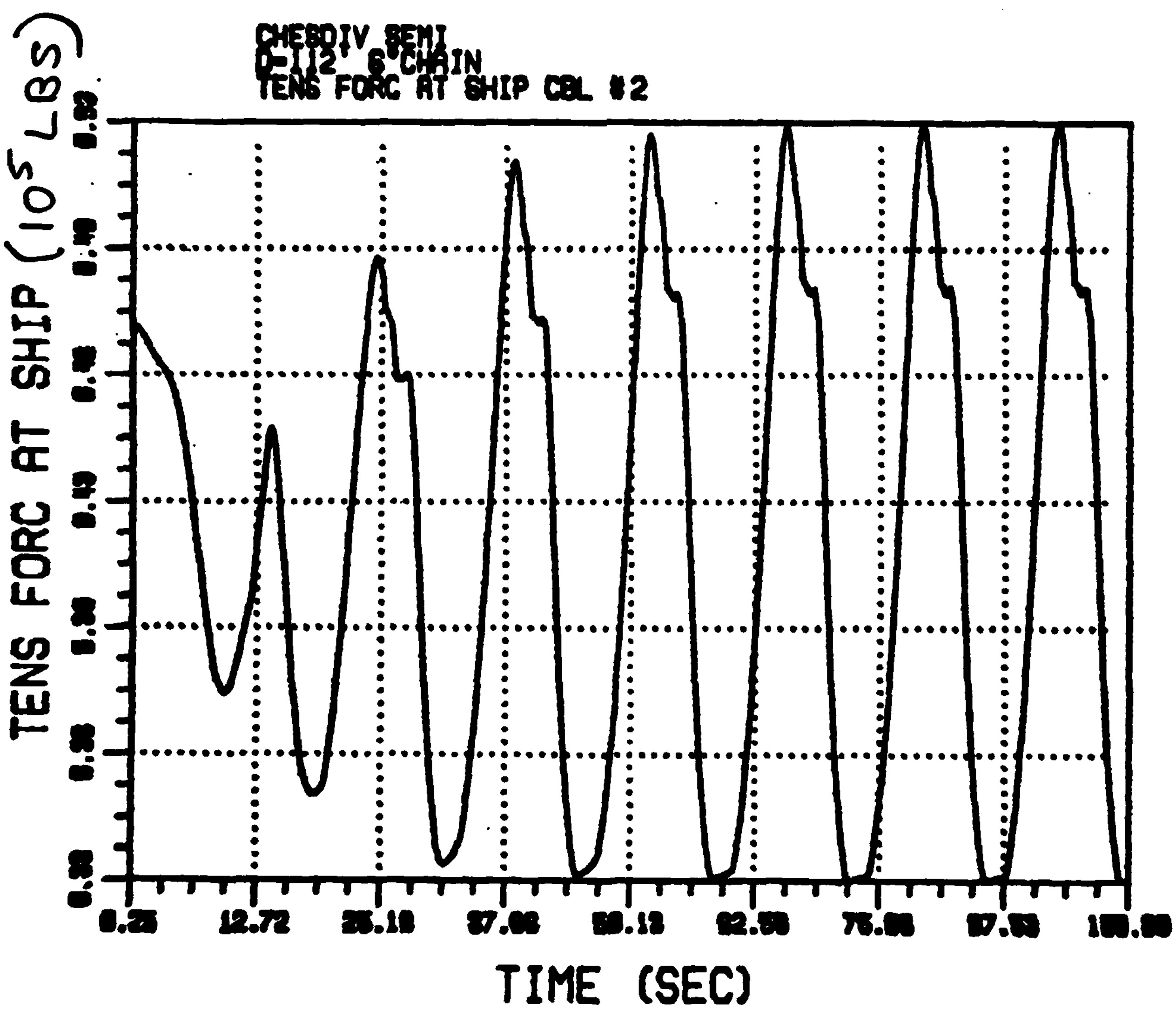
CHESDIV SEMI
D-112' 6"CHAIN
VERT FORC AT ANCH CBL #1
VERT FORC AT ANCH (10⁵ LBS)
12.72
25.19
TIME (SEC)

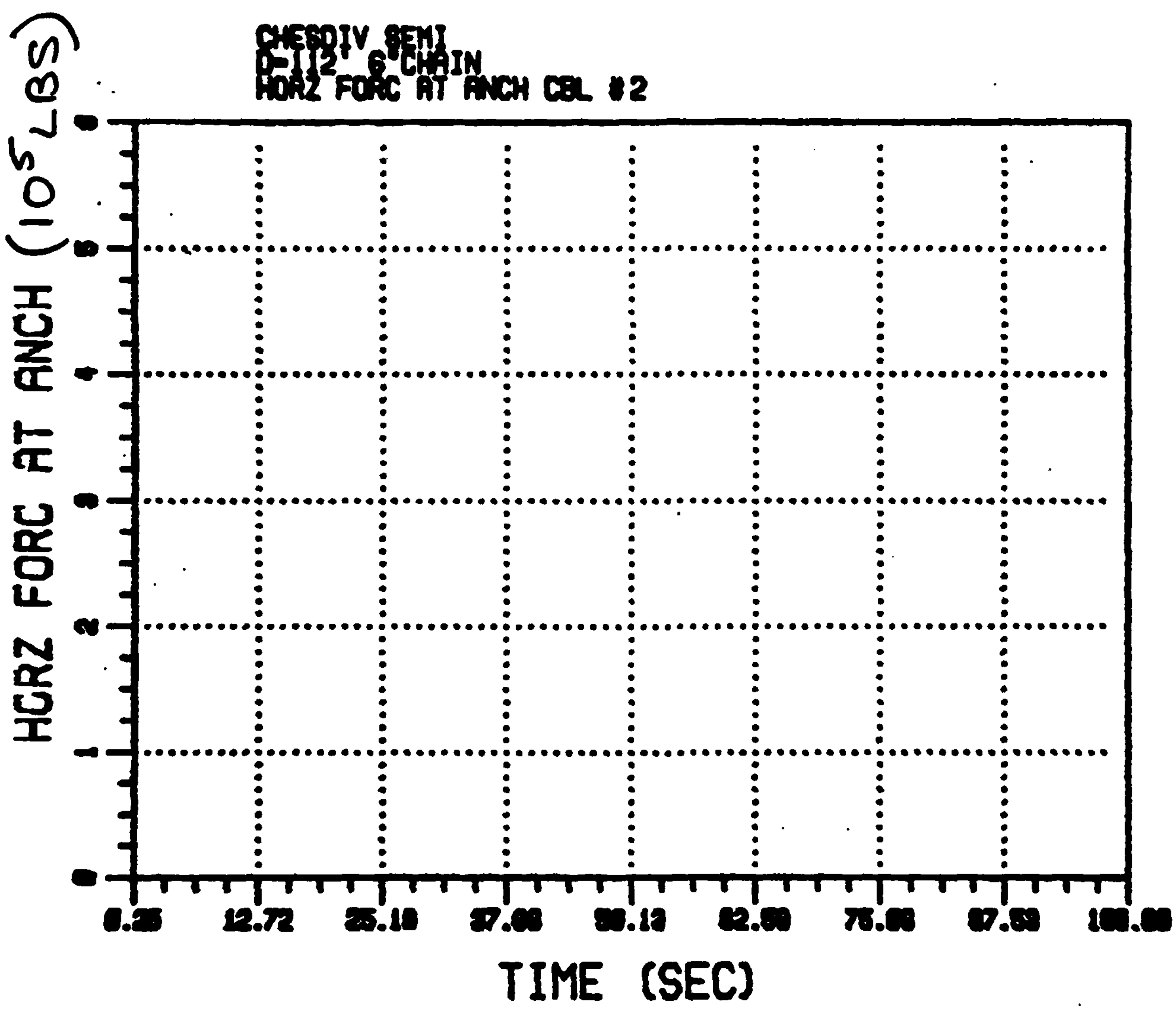


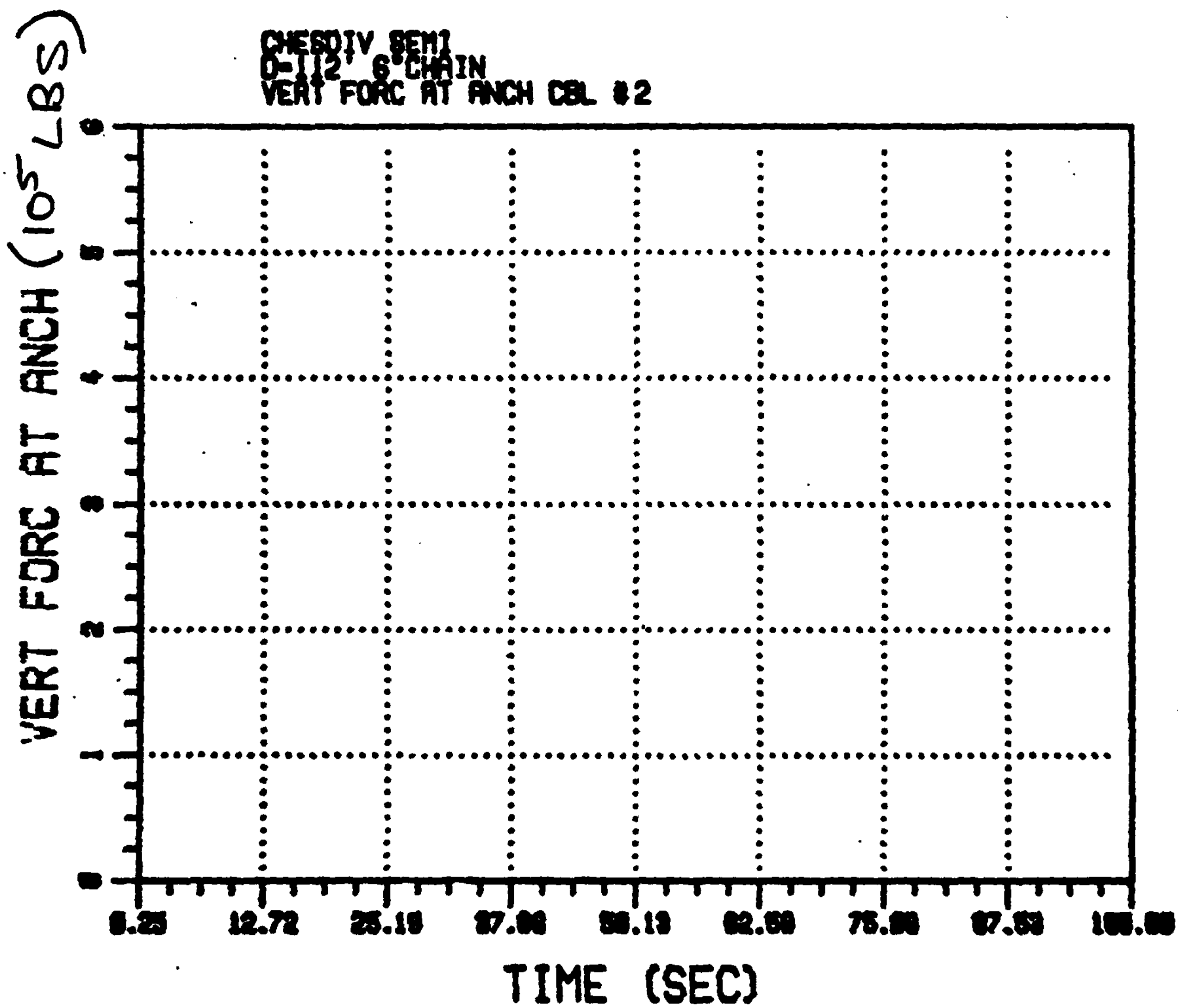
CHESDIV SEMI
D-112' 6"CHAIN
HORZ FORC AT SHIP CBL #2
HORZ FORC AT SHIP (10^5 LBS)
12.72
25.19
37.66
TIME (SEC)



CHESDIV SEMI
D-112' 6"CHAIN
VERT FORC AT SHIP CBL #2
VERT FORC AT SHIP (10^5 LBS)
12.72
TIME (SEC)


CHESDIV SEMI
D-112' 6" CHAIN
TENS FORC AT SHIP CBL #2
TENS FORC AT SHIP (10^5 LBS)
12.72
TIME (SEC)


CHESDIV SEMI
D-112' 6" CHAIN
HORZ FORC AT ANCH CBL #2
HORZ FORC AT ANCH (10^5 LBS)
2
4
12.72
TIME (SEC)



CHESDIV SEMI
D-112' 6"CHAIN
VERT FORC AT ANCH CBL #2
VERT FORC AT ANCH (10^5 LBS)
12.72
TIME (SEC)

SUMMARY OF RESULTS

EFFECTIVE WATER DEPTH = 112 FT

DESIGN WAVE HEIGHT (FT) = 61.0
WAVE PERIOD (SEC) = 13.6
MAX CREST ELEVATION (FT) = 43.65
MIN TROUGH ELEVATION (FT) = −16.85
MEAN ELEVATION (FT) = +13.40

MAX/MIN SURGE OFFSET (FT) = −43.62/18.35
MEAN SURGE OFFSET (FT) = −12.63
MAX 1st ORDER MOTIONS (FT) = ± 31.0

MAX/MIN HEAVE OFFSET (FT) = 17.18/−15.13
MEAN HEAVE OFFSET (FT) = +1.03
MAX 1st ORDER MOTION (FT) = ± 16.15

MAX/MIN PITCH ANGLE (DEG) = 9.94/−22.48
MEAN PITCH ANGLE (DEG) = −6.27
MAX 1st ORDER MOTION (DEG) = ± 16.2

MAX HORIZONTAL FORCE @ VESSEL (KIPS) = 1843
MIN HORIZONTAL FORCE @ VESSEL (KIPS) = 0
MEAN HORIZONTAL FORCE @ VESSEL (KIPS) = 927

MAX VERTICAL FORCE @ VESSEL (KIPS) = 322
MIN VERTICAL FORCE @ VESSEL (KIPS) = 0
MEAN VERTICAL FORCE @ VESSEL (KIPS) = 161

MAX TENSION @ VESSEL (KIPS) = 1871
MIN TENSION @ VESSEL (KIPS) = 0
MEAN TENSION @ VESSEL (KIPS) = 935.5

MAX HORZ. FORCE @ ANCHOR (KIPS) = 1597
MIN HORZ. FORCE @ ANCHOR (KIPS) = 0

MAX VERTICAL FORCE @ ANCHOR (KIPS) = 0
MIN VERTICAL FORCE @ ANCHOR (KIPS) = 0

CHAIN DIAMETER (IN) = 6
LENGTH OF CHAIN (FT) = 2,000
LOCATION OF ANCHOR (FT) = 1,950
PROOF LOAD (KIPS) = 1,629

(PEAK TENSION / PROOF LOAD) × 100 = 114.8%

bwa

END
FILMED
3-86
DTIC